THREE-D GEOCONSULTANTS LIMITED

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Open File Report 89-35

INVESTIGATION OF THE MARKET POTENTIAL FOR MINERAL FILLERS FROM NEW BRUNSWICK

by

Three-D Geoconsultants Limited
and
ADI Limited

Fredericton, New Brunswick

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CHAPTER 1.0: INTRODUCTION

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1.0 INTRODUCTION

Mineral fillers are finely ground minerals or rock used to improve the physical properties or increase the bulk of manufactured products. Used in a wide range of industrial applications, such materials often form important components of numerous commonplace commodities. For example, finely ground carbonate or kaolin are utilized in the manufacture of many paper products as fill between the wood fibers. In this case the filler material is a low-cost additive enhancing the quality characteristics of the product.

The term mineral extender, is often used interchangeably with the term mineral filler. Fillers often are used to extend, or stretch out, the characteristics of key components in a manufactured product. For example, the use of fillers in paint reduces the quantity of pigment required.

A wide range of minerals are used as fillers. In addition, the consumption of fillers is a very diverse market and, in many cases, has unique and specialized requirements. The variation in product characteristics and consumer requirements result in a complex interaction of competing and substitute products that must be evaluated on the basis of price, function, availability, and transportation factors.

1.1 Study Objectives and Scope

The objective of the present study is a comprehensive and contemporary assessment of the market potential for filler applications of selected industrial minerals. The minerals included in the scope of the study are barite,

limestone, dolomite, kaolin, and silica. For convenience, limestone and dolomite have been grouped under the general term carbonates and are addressed as a single commodity.

The mineral commodities included in the study were specified prior to commencement of the investigation and were selected on the basis of existing production, or potential for production, of these materials in the Province of New Brunswick. Carbonate products are presently available at five locations in the Province and silica at two locations. Kaolin is not presently produced but is a component of unused fine tailings material from an existing mineral producer. Barite occurrences have been evaluated in southern New Brunswick and, while development is not being actively pursued, barite is considered to have potential for production.

1.2 Study Area and Report Organization

The study area for the market evaluation includes the Atlantic Provinces, Quebec, and eastern Ontario, in Canada and the eastern coastal United States (south to the Delaware-Maryland boundary). This market area essentially corresponds to a one-day trip for a truck carrying product from a hypothetical mineral filler operation located in New Brunswick. The study area is shown diagrammatically in Figure 1-1.

Figure 1-1 Location map of the study area.

The study, funded under the 1984-89 Canada-New Brunswick Mineral Agreement (MDA), has been conducted by Three-D Geoconsultants Limited and ADI Limited of Fredericton, under contract with Supply and Services Canada on behalf of Energy Mines and Resources Canada. The New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, has provided technical supervision in the course of the study.

The study has been structured on the basis the individual mineral commodities. The report contains one chapter for each of the selected mineral commodities. Introductory remarks and sections specific to transportation issues have also been included in the report. Such a structure facilitates the use by those persons interested in a specific mineral commodity. Each of the four commodity chapters have been developed on an individual basis and each has a detailed table of contents specifically for the chapter. The main table of contents has been generalized so that only first and second order section headings are shown. Lists of Tables and Figures are provided with the detailed Table of Contents associated with each chapter. The page numbers are prefixed with the chapter number and the sequence is internal to the chapter.

Although each chapter has been developed independently, certain components of the report can be applicable to more than one commodity. For example, consumption of the four mineral filler commodities by the paint industry has been discussed in each individual chapter. However, certain elements of the information (such as distribution of the market, background information on the function of fillers in paint, etc.,) are to a large degree common to all of the commodities. Rather than repeat detailed data in each

chapter, the salient features of the general information are reviewed in each chapter and a cross-reference to more detailed treatment of the information is provided as applicable.

1.3 Properties of Mineral Fillers

Mineral commodities used for filler applications are typically evaluated on the basis of several key properties. These properties include: particle size and shape (and particle size distribution); brightness (whiteness); chemical or mineralogical purity; hardness or abrasiveness; and oil absorption. In some cases, the mineral commodities will fulfil the requirements with minimal processing of the material extracted at the mine site. In other cases substantial beneficiation or modification is required.

The methods of classification or evaluation of many of these properties are somewhat specialized. To enhance the understanding of the body of the report, a brief review of some of the terminology commonly used in the specification of requirements for mineral fillers has been provided.

1.3.1 Particle Size

The particle size distribution is one of the most important factors in the evaluation of a mineral filler. In general, particle size distribution refers to the percentage of material retained on (or passing) various sieve sizes. In practice, a mineral filler is usually screened (subsequent to grinding, etc.) to be within a certain size range. Coarser or finer material may be suitable for other applications.

A common specification would be that 95 percent of the material passes a 325 mesh (45 micron) sieve. A more stringent specification would be that the material be within the 10 to 30 micron range. The largest sieve size of the range is often called the "top size" whereas the smaller sieve size is referred to as the bottom size. A test result for a filler material could be quoted as "average size 3 microns, top size 10 microns".

The particle size distribution is one of the most important factors in the determination of the acceptability and value of a mineral filler. The range of particle sizes, the average and maximum particle sizes, and the sharpness of the top and bottom size cuts are among the parameters considered. In general, the finer the material, the sharper the top and bottom separations, and the narrower the size range, the higher the price the product can command. The density of a filler product tends to decrease as particle size becomes smaller (higher void ratio). Finer filler grades are regarded as having higher flowability, since they can increase the viscosity in some systems and yield smoother surfaces. The maximum particle size and the sharpness of the size limits are critical in certain applications such as when surface gloss is an important component of the finished product.

In the fine size ranges, classifications using standard sieves becomes impractical and specialized equipment is used. The Fisher particle size analyzer is one example. Another is the Hegman gauge which determines the coarseness (i.e., the size of the larger particles) of a filler product. The result is expressed numerically as the Hegman Grind. The Hegman Grind number is generally inversely proportional to the particle size, i.e., the Hegman number increases as the grind becomes finer.

Particle shape is also a factor in certain filler applications. Rounded or angular particles can affect the flow characteristics, surface gloss, and/or texture of the manufactured product. Elongated particles can provide structural reinforcement. Platy minerals such as kaolin can provide a surface film.

Terms such as coarse, medium, fine and ultrafine are often used in a discussion of mineral fillers. However, these terms do not have universally defined limits or requirements. One definition of fine can be substantial different from another. Thus contract specifications are usually based on specific particle size distributions. However, these terms are frequently used in a general context and were common in reference material used in this study. For the purposes of convenience, Table 1-1 has been prepared to provide an overview of the range of sizes associated with these terms.

1.3.2 Whiteness

The colour or the degree of whiteness is an important factor in many filler applications. In general, the finer the size of the filler material the higher the degree of whiteness. Brightness is a method of expressing the whiteness and is a common component of specifications. Brightness is determined on the basis of measured reflectance relative to a pure magnesium carbonate standard. The result is expressed on a percentage basis as G.E. brightness. The brightness, or whiteness, increases as the percentage approaches one hundred. Fillers having G.E. brightness values of 94 or greater are considered to have high brightness.

	Average Particle Size (microns)	Maximum Particle Size (microns)
Coarse	25 to 30	150 to 200
Medium	12 to 22	50 to 100
Fine	3 to 10	15 to 35
Ultrafine	1 to 2	5 to 10

Note: Terms and ranges are for discussion purposes only and do not have universally accepted limits or definitions.

Table 1-1: Typical size ranges of filler materials.

1.3.3 Other Properties

Several other properties can be of importance for many filler applications. The chemical and/or mineralogical purity is critical to certain processes particularly when acids or low pH conditions are a component. In addition the presence of abrasive minerals can be a factor. Dark coloured minerals can affect product colour. Similarly the presence of certain trace elements can influence colour or react with other materials in the manufactured product.

Hardness of the filler material can be a factor in situations where structural reinforcement is important. Density and specific gravity are critical to certain applications. Oil absorption properties are important in filler use in applications such as for paint manufacture. Flame retardancy, opacity, and similar properties can be important in specialized uses.

Filler consumption is very diverse and the requirements are often specific to a particular application and end use. To satisfy the requirements of the market, a producer of filler materials must be able to process, modify, or beneficiate the material to meet the individual specifications of the consumer. Table 1-2 presents an overview of the key properties and functions the filler minerals considered in this study.

1.4 Consumption of Mineral Fillers

The major markets for mineral fillers are the paper, plastic, and paint industries. Rubber, carpet backing, putty, caulks and sealants, adhesives, inks and a wide variety of other products also contain significant amounts of fillers. Specifications and requirements vary between industries and between products. In some cases, one filler commodity represents a substitute or competing product to other fillers.

Table 1-3 presents an overview of the principal consuming industries of the study minerals for filler purposes. The percentage of the total filler market for each study mineral is shown according to user industry. The data shown in the table are compiled from various sources and are discussed in greater detail in the applicable sections of the report.

Mineral	Special Properties	Function
Barite	High specific weight Chemically inert Acid and alkali resistant Low oil absorption High brightness Low abrasion	Adds weight Carries pigment Reduces cost Opacifies
Carbonates		
Ground	High brightness Low oil absorption	Reduces Cost
Precipitated	High brightness Good ink absorption	Coats paper Thickener
Kaolin		
Air-floated	Fine Particle Size	Reinforcement
Water-washed	High brightness Good Gloss Good Rheology (Flow)	Coats paper Fills paper
Calcined	Dielectric strength Dry hiding	Insulation Opacifies
Surface-Treated	Good dispersion	Reinforcement
Silica		
Ground	Inertness Abrasion Resistance	Reduces gloss (flattens) Reduces cost Reinforcement

Table 1-2: Key properties and functions of the minerals included in the study.

User Industry	Percentage of Overall Consumption			
	Barite	Carbonates	Kaolin	Silica
paint	65	12	4	78
paper	--	7	86	--
plastics	25	20	5	12
putty, caulk, sealants and adhesives	1	6	2	5
rubber	6	6	3	5
carpet backing	3	25	--	--
joint compounds	--	24	--	--
	100%	100%	100%	100%

Table 1-3: Percentage of overall consumption of the study minerals according to utilization type.

In an effort to further "set the scene" for the detailed discussions that follow, a series of four maps (Figures 1-2 to 1-5) have been prepared. These figures show the distribution (i.e., number of manufacturing plants, etc.) of consuming industries according to state and province within the study area. Detailed tables showing the levels and types of fillers consumed by these industries are given in the applicable sections of the report.

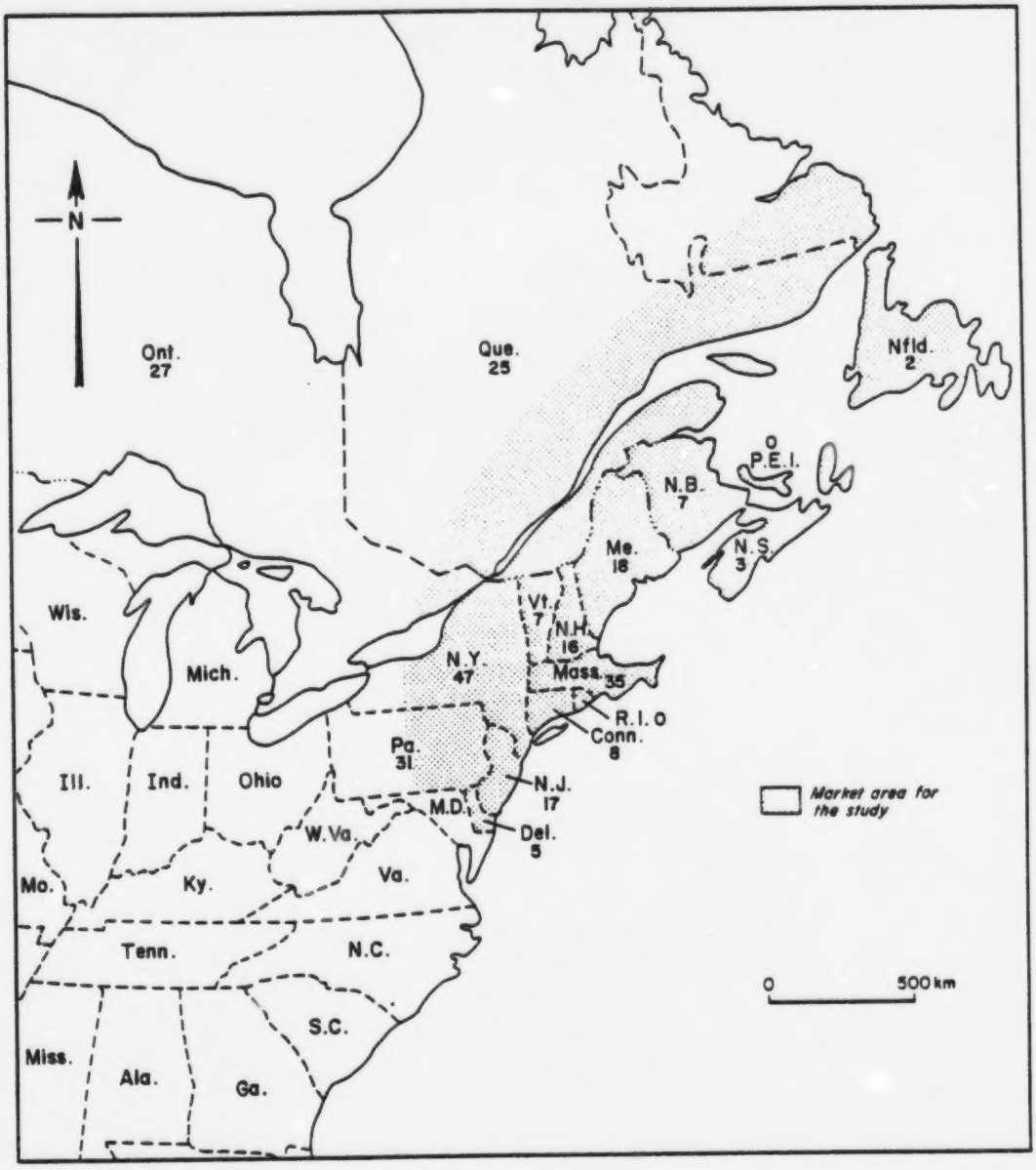

Figure 1-2 Distribution of paper mills in the study area.

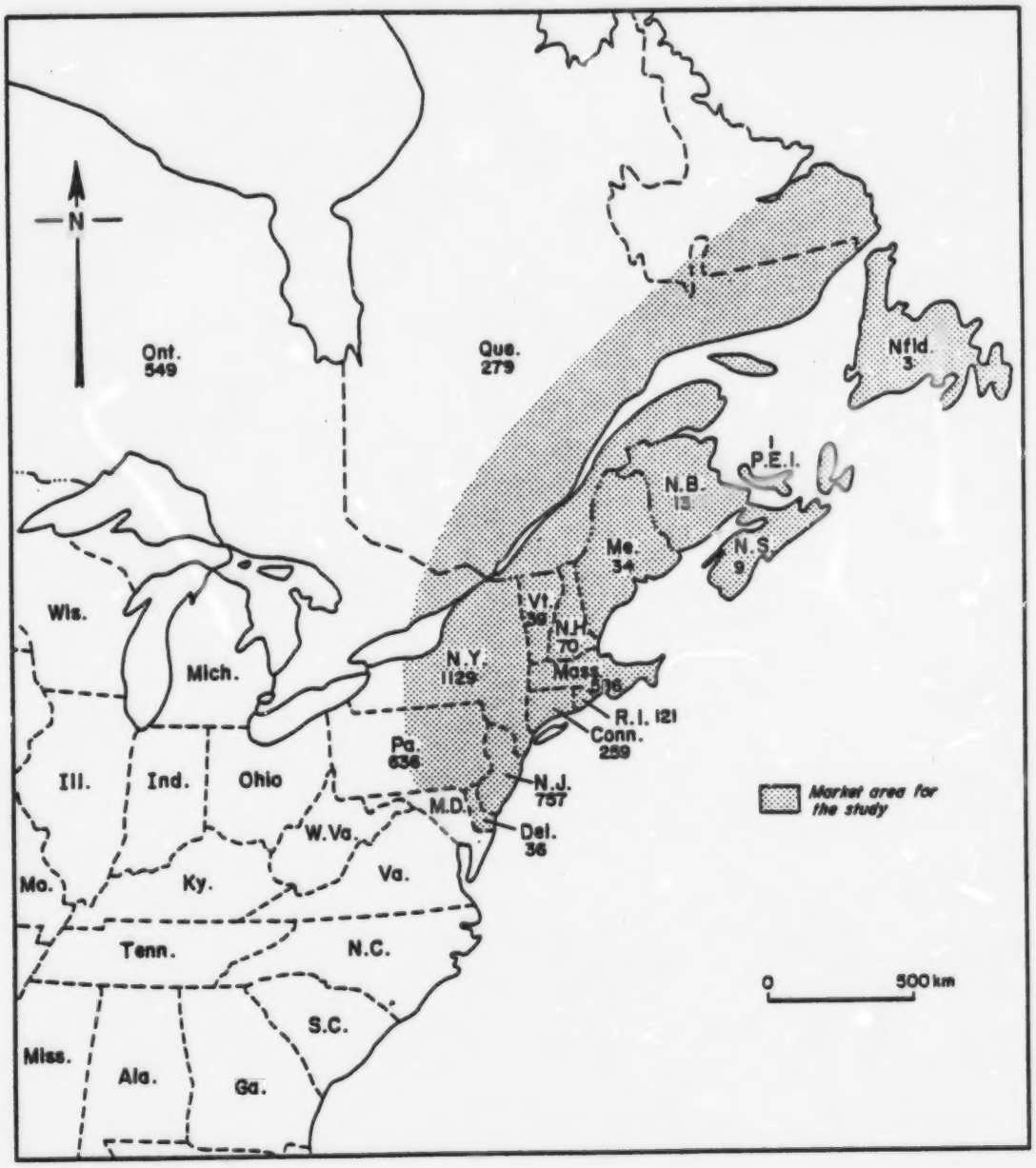

Figure 1-3 Distrubution of manufactures of plastic producers in the study area.

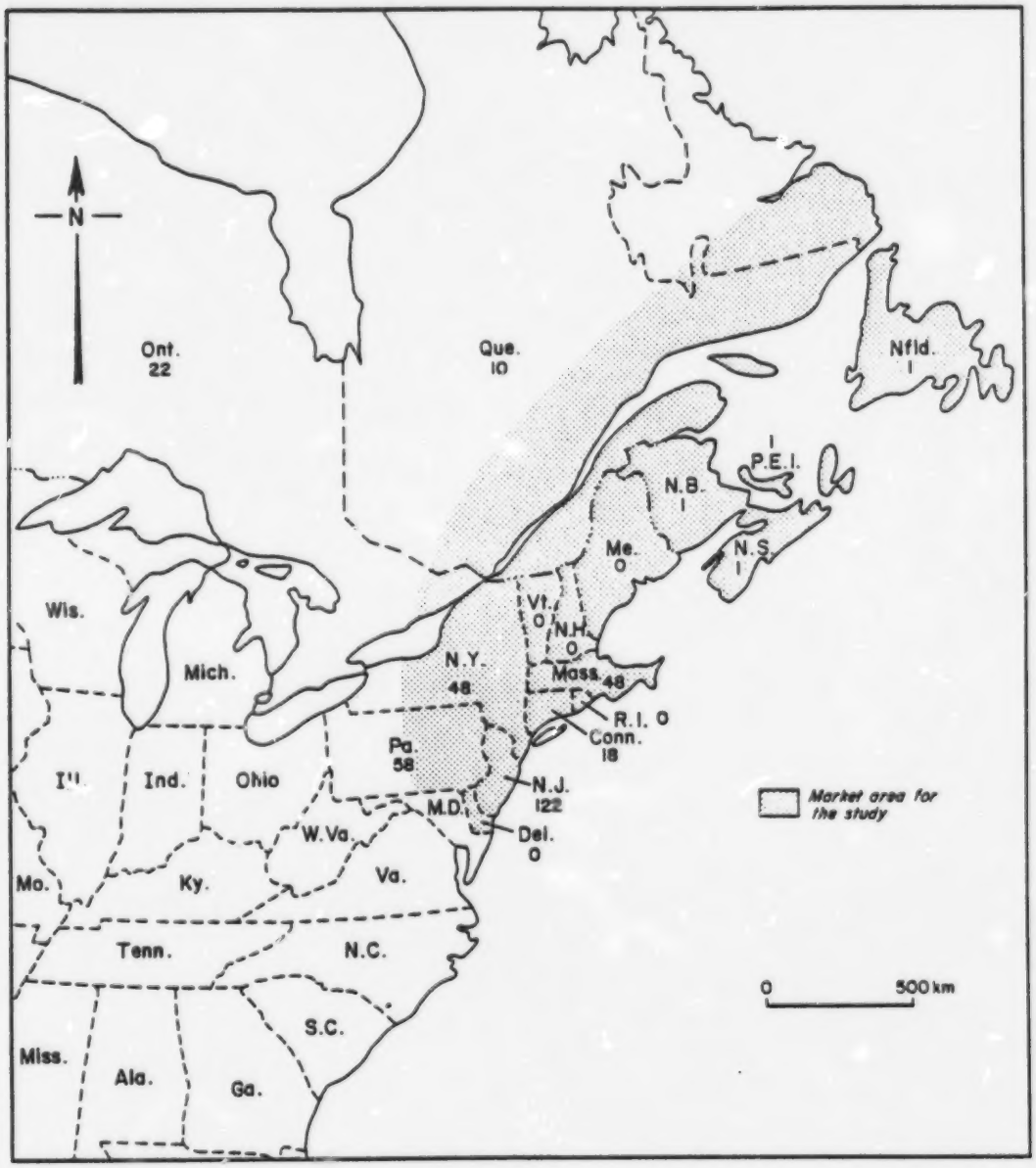

Figure 1-4 Distribution of manufacturers of paint and allied products in the study area.

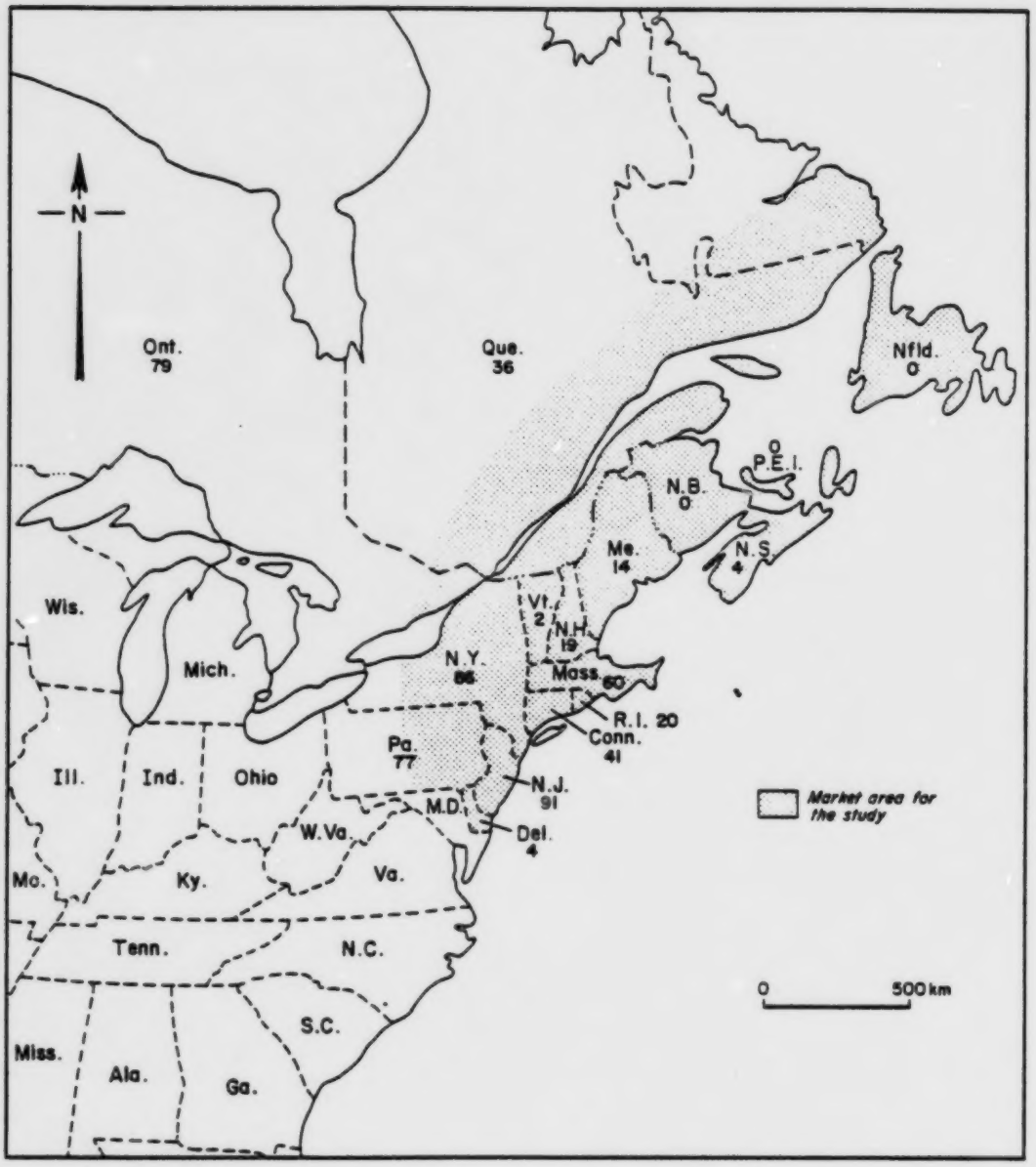

Figure 1-5 Distribution of manufacturers of rubber and plastic products in the study area.

CHAPTER 2.0: BARITE

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2.0 BARITE

2.1 Introduction and Overview

Barite is the mineral name for barium sulphate ($BaSO_4$). The mineral occurs naturally in vein, bedded and residual deposits. Open pit mines or quarries are the most common method of recovering barite but underground methods can also be used. The material is typically crushed and passed through a grinding circuit. Depending on the end use, secondary processing methods such as gravity separation, flotation, washing with sulphuric acid, and air classification may also be used.

The key attribute of barite is its high specific weight (specific gravity of 4.4) making it the heaviest of common, non-metallic minerals. Other important properties include high brightness and low abrasion.

About 85 percent of the world production of barite is used as a weighting agent in oil and gas well drilling. Its high specific weight is an important property for the drilling muds used to stabilize the walls of drill holes to control oil and gas pressures which can be encountered. The remaining 15 percent is consumed in the production of various barium-based compounds, in the manufacture of glass and ceramics, in pharmaceuticals and as a filler and extender in the manufacture of plastics, rubber, paint, adhesives and sealants.

The largest consumer for filler purposes is the paint industry where barite is used because it is chemically inert, acid and alkali-resistant, and has low oil absorption characteristics.

High specific weight, inertness, and resistance to acids and alkalis are the key reasons for using barite as a filler in plastics, rubber, putty, caulks and sealants.

Barite is relatively expensive compared to other filler minerals. As a result it has been displaced from many traditional uses (e.g. by calcium carbonate in paints) and the rate of consumption has fallen in recent years.

2.2 Production of Barite

2.2.1 Location and Capacity of Producers

There were 29 primary producers of barite in North America in 1987 (Table 2-1, Figure 2-1) but only four were major producers of the filler material (Shaw and Boucher 1987).

The four producers are:

1. Mountain Minerals Co. Ltd., Lethbridge, Alberta, (material mined in Northern British Columbia and processed in Lethbridge).

2. Extender Minerals of Canada Limited, Matachewan, Ontario.

3. Paga Mining Co. (a subsidiary of Thompson Weimann and Company), Georgia.

4. C.R. Wood Company Inc., Tennessee

Company	Parent Corporation	Plant Capacity (t/a)	Market Applications
1. M-I Drilling Fluids Canada, Inc.	-	n.a.	Drilling fluids
2. NL Chem Canada, Inc.	N L Industries, Inc.	25 000	Drilling fluids
3. Mountain Minerals Co. Ltd	-	140 000	Drilling fluids fillers and extenders
4. Extender Minerals of Canada Limited	-	13 500	Fillers and extenders
5. Mystone Chemicals Ltd.		15 000	Pharmaceuticals
6. C-E Minerals, Inc.	-	40 000	Drilling fluids
7. Chromalloy American Inc.	-	200 000	Drilling fluids
8. All Minerals	-	200 000	Drilling fluids
9. Circle A Mining Co.	-	n.a.	Drilling fluids
10. Milchem/Milpark Incorporated	Baker Hughes Incorporated & Eisenmann Chemical Co.	180 000	Drilling fluids
11. M-I Drilling Fluids Canada, Inc.	-	225 000	Drilling fluids
12. M-I Drilling Fluids Canada, Inc.	-	200 000	Drilling fluids
13. NL Chem Canada, Inc.	N L Industries	270 000	Drilling fluids
14. Custom Milling Company	-	50 000	Drilling fluids
15. Barite Company of America	-	150 000	Drilling fluids
16. Old Soldier Mining Company	-	110 000	Drilling fluids
17. Milchem/Milpark Incorporated	Baker Hughes Incorporated & Eisenmann Chemical Co.	160 000	Drilling fluids
18. M-I Drilling Fluids Canada, Inc.	-	200 000	Drilling fluids
19. a) Milchem/Milpark Incorporated	Baker Hughes Incorporated & Eisenmann Chemical Co.	130 000	Drilling fluids
b) M-I Drilling Fluids Canada, Inc.		n.a.	Drilling fluids
20. a) Hughes Drilling Fluids	W.R. Grace and Company	n.a.	Drilling fluids
b) Chromalloy American Inc.	-	240 000	Drilling fluids
c) M-I Drilling Fluids Canada, Inc.	-	400 000	Drilling fluids
21. Old Soldier Mining Company	-	(1)	Drilling fluids
22. DL Mud Co.	-	250 000	Drilling fluids
23. a) Milchem/Milpark Incorporated	Baker Hughes Incorporated & Eisenmann Chemical Co.	260 000	Drilling fluids
b) M-I Drilling Fluids Canada, Inc.	-	n.a.	Drilling fluids
24. a) Hughes Drilling Fluids	W.R. Grace and Company	n.a.	Drilling fluids
b) Chromalloy American Inc.	-	240 000	Drilling fluids
c) M-I Drilling Fluids Canada, Inc.	-	200 000	Drilling fluids
25. DeSoto Mining Company	Galveston-Houston Company	50 000	Drilling fluids, chemicals
26. N L Industries, Inc.	-	n.a.	Chemicals
27. M-I Drilling Fluids Canada, Inc.	-	75 000	Drilling fluids
28. a) Paga Mining Co.	Thompson Weimann & Company	25 000	Fillers and pigments
b) New Riverside Ochre Company	Chemical Products Corp.	28 000	Chemicals
29. CR Wood Company Inc.	-	6 000	Fillers and pigments

(1) Combined plant production at Old Soldier Mining Company's two locations is 110 000 t/y
n.a. Not available; - Nil.

Table 2-1: Primary producers of barite in the United States and Canada (Shaw and Boucher, 1987). See location map - Figure 2-1.

Figure 2-1 Location map of barite producers, Canada and the United States, 1987 (Shaw and Boucher 1987).

In addition, there were ten suppliers of filler which bought primary barite from North American or offshore producers (Ampian 1986):

1. American Minerals Inc., Camden, NJ and Rosidare, IL.

2. Circle A Construction, Wells, NV.

3. Clark Minerals Inc., South Plainfield, NJ.

4. Coastal and Western Minerals Co., Knippa, TX.

5. Extender Products Ltd., Mineral Point, MO.

6. Magcobar Minerals Div., Dresser Industries Co, Brownsville, TX and West Lake Charles, Ltd.

7. The Milwhite Co., Brownsville, TX and Chatsworth, GA.

8. Minerals, Pigments and Metals Div., Pfizer Inc., St. Louis, MO.

9. NL Baroid/NL Industries Inc., Potosi, MO.

10. Standard Industrial Minerals, Laws, CA.

2.2.2 Mining, Processing and Beneficiating Technology

2.2.2.1 Mining

Barite deposits consist of three commercially mineable types: vein deposits, bedded deposits and residual deposits. Most bedded and residual barite is quarried using conventional methods while vein barite is often mined underground.

Residual deposits consist of barite lumps or nodules in a layered soil or clay which have resulted from the weathering of bedrock containing barite. The barite is separated from the soil by washing and from lumps of chert, quartz or other coarse impurities by screening and size reduction - the barite lumps being softer than chert or quartz.

Bedded deposits occur in stratiform sequences, often as replacement of limestone. These deposits are usually quarried although, occasionally, underground mining is used if thick overburden is present.

Vein barite deposits result from the movement of solutions rich in barium sulphate through breccia zones or fractures and subsequent deposition of the barite. Vein barite is usually mined underground although some quarrying can be used on surface exposures. Barite can also be extracted from abandoned mine tailings at some locations.

2.2.2.2 Processing and Beneficiation

The high specific weight of barite facilitates the use of gravity methods to separate it from gangue minerals such

as calcite and fluorite to produce a concentrate. Tabling, jigging, spiral separation, and flotation methods are also used as beneficiation processes depending upon the type and grade of raw material. These processes are often preceded by crushing and grinding (See Figures 2-2 and 2-3).

Secondary processing and beneficiation of barite is used to bring the material up to filler or pharmaceutical standards. Washing with sulphuric acid often improves barite whiteness. Grinding and air classification are dry processes used to beneficiate barite; wet processes include grinding, centrifuging or hydrocycloning, drying (rotary, flash, or fluid bed dryers), and air classification (Guillet and Kriens, 1984).

2.3 Utilization and Consumption

The largest use of barite is as an additive in well-drilling muds. Drilling mud uses the high specific weight of barite to maintain the wall stability of drill holes and to counteract the pressure of gas and oil during petroleum drilling. In Canada, drilling muds accounted for 15,000 tonnes (66.1%) of the 22,700 tonnes of barite consumed in 1988; in the United States well-drilling muds accounted for 91.0% of the 1,100,000 tonnes consumed there in 1986.

Fillers, chemicals, and glass are the other major uses for barite. Of the filler uses, the most important are paints, plastics, rubber, carpet backing, adhesives, and putty, caulks and sealants (Shaw and Boucher 1987, Ampian 1986). Estimated barite filler consumption in North America by use for 1980 to 1985 is (Guillet and Kriens 1984):

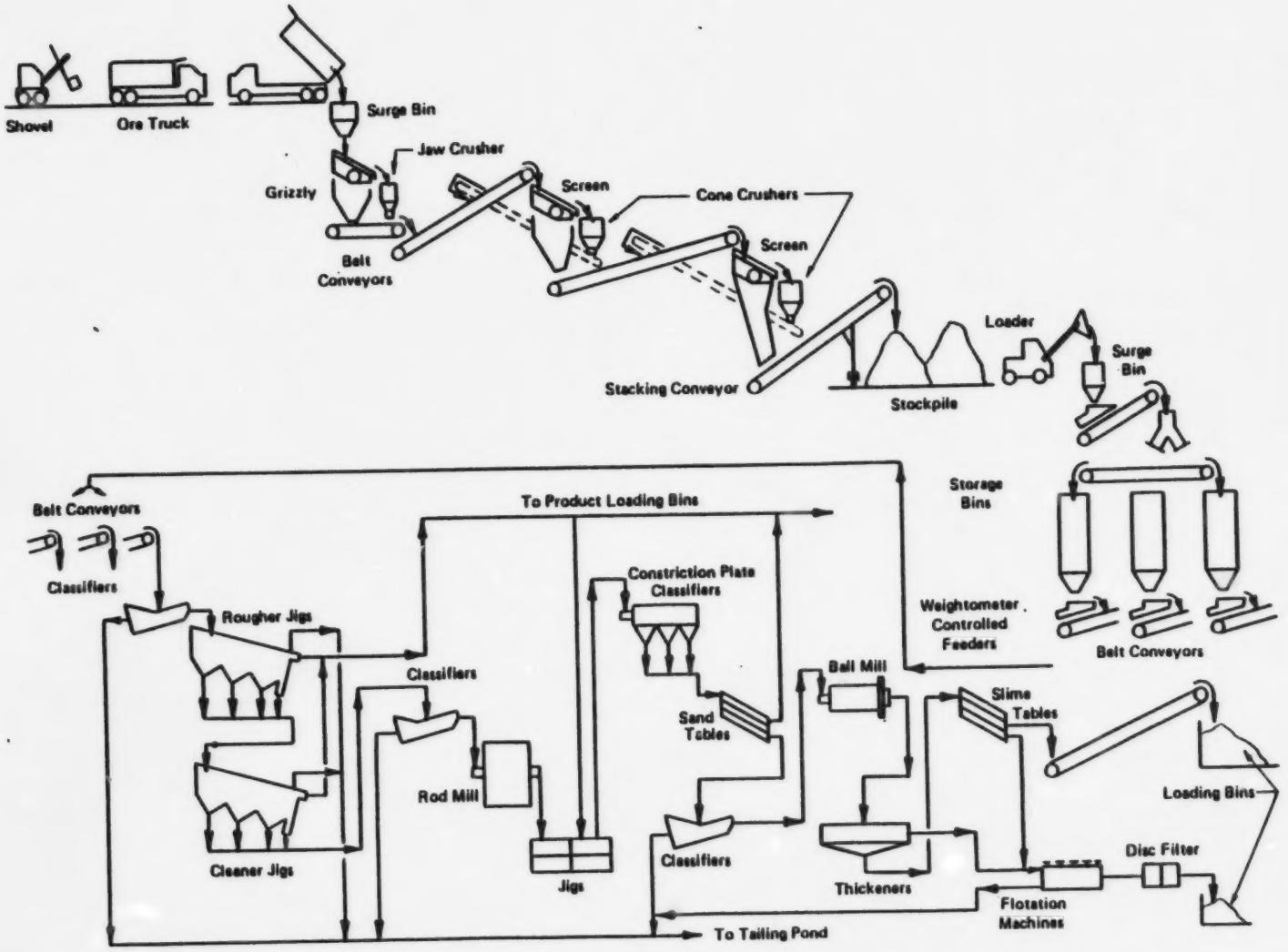

Figure 2-2 Flowsheet of barite concentrator, Mountain Springs, Nevada (Guillet and Kriens, 1984).

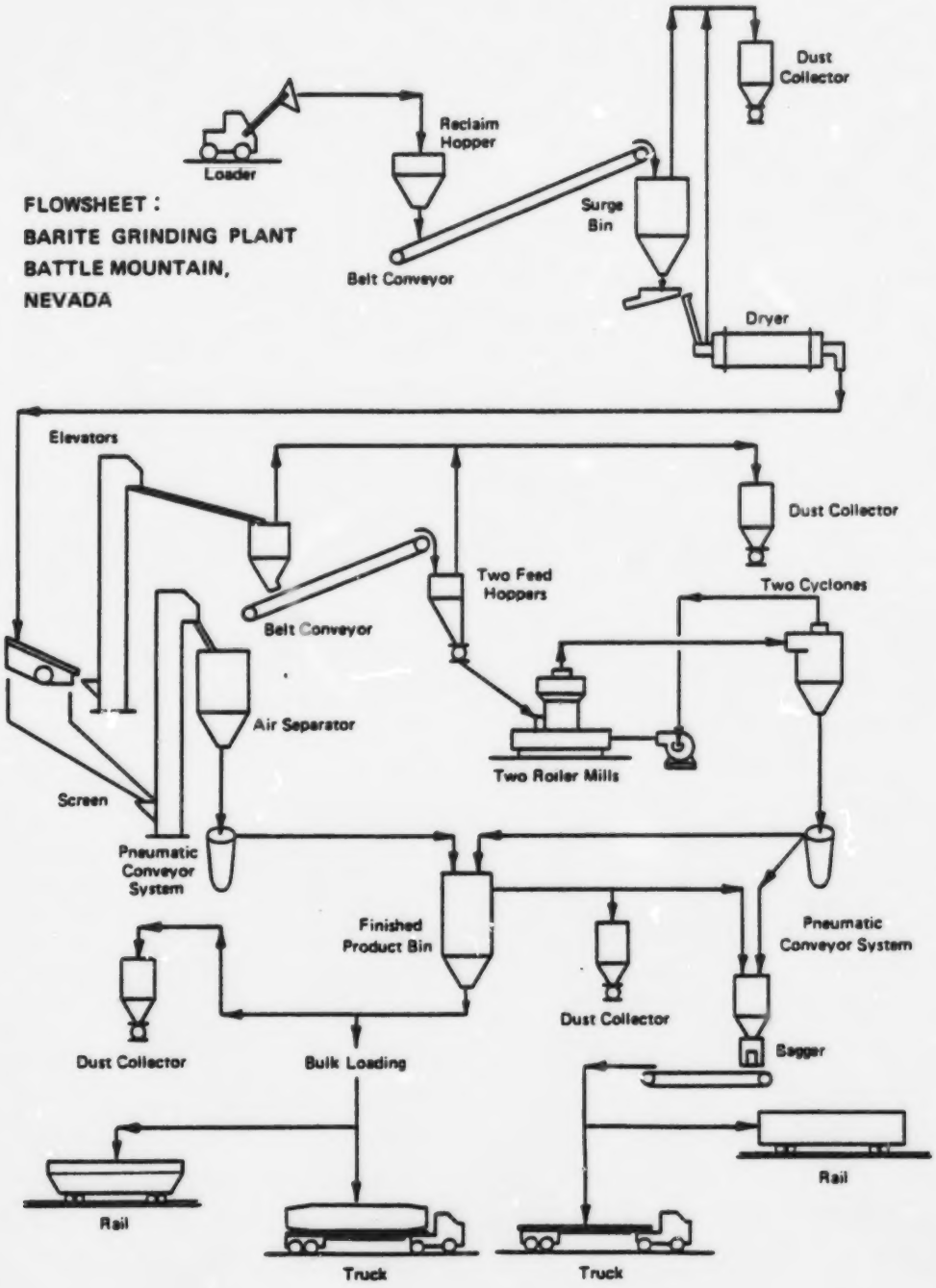

Figure 2-3 Flowsheet of barite grinding plant, Battle Mountain, Nevada (Guillet and Kriens 1984).

Paint	42,000 tonnes/year (65%)
Plastics	16,000 (25%)
Rubber	4,000 (6.2%)
Carpet Backing	2,000 (3.1%)
Putty, Caulks, Sealants	500 (0.7%)
TOTAL	64,500

2.3.1 Paint Industry

2.3.1.1 Background

"Liquid paint is a dispersion of a finely divided pigment (or vehicle) in a liquid composed of a resin or binder and a volatile solvent" (Austin 1984).

Paints are one of a series of surface-coating compounds. Other coatings include: varnishes (clear), enamels (pigmented varnishes), lacquers (film formed by evaporation), printing inks, polishes, and plastic resins.

Paint forms a coat or film through the polymerization of a polyunsaturated oil. The purposes of the pigments are to add colour to the film and reflect destructive light rays from the coated object. Pigment extenders or fillers, in turn, reduce the cost of paint and increase its durability by reducing the quantity of pigment required and enhancing pigment properties. In some cases, fillers are used as carriers: the pigments are precipitated upon the carriers (clay, barite) forming "lakes" of colour.

The selection and formulation of paints depends upon both the anticipated application and environmental conditions. Considerations include hiding power, colour,

weather resistance, washability, gloss, metal anticorrosive properties, ease of application and consistency. Using the proper mix of pigments, extenders, and vehicles, chemists can produce a paint for almost any condition.

Determination of the proper amount of pigment and extender to use in a paint is a function of the pigment volume concentration (PVC).

$$PVC = \frac{Vp}{Vp + Vnv}$$

Where: Vp = volume of pigment in paint
Vnv = volume of nonvolatile vehicle constituents in paint , i.e., the components remaining after the paint has dried (Austin 1984).

The PVC range of acceptable values varies with the type of paint (Austin 1984):

Flat Paints	50-75%
Semigloss Paints	35-45%
Wood Primers	35-40%
Exterior House Paints	28-36%
Metal Primers	25-40%
Gloss Paints	25-35%

2.3.1.2 Applications

The paint industry is the largest consumer of barite fillers. Barite is dense, chemically inert and highly resistant to water, acid and alkalies resulting in a strong, resistant paint film. Like all good paint fillers barite

has low oil absorption and high oil wettability, meaning that it requires a low level of oil to serve as a binder, thereby reducing the amount of expensive oil required in the paint.

Types of paint using barite include automotive and industrial metal (anti-rust) primers (good sanding properties, good adherence, high gloss), floor enamels (good wear, chemical resistance), and water-based, semi-gloss exterior paints (good weathering, good caulking properties). (Belcher 1948, Boxall and von Fraunhofer 1976, Prud'homme and Francis 1987a).

2.3.1.3 Specifications

For paint barite must have medium (primers) to high (trade-sales paints) brightness with a fine particle size of controlled variation. Low oil absorption is required but is a natural property of barite. Sometimes the barite is bleached to attain the specified brightness (Guillet and Kriens, 1984). Table 2-2 provides specifications for barite fillers in paint.

Barite does not possess any pigmentry properties but enhances the optical properties of pigments by enhancing the distribution of pigment throughout the paint mixture (Griffiths 1984).

Particle size for paint should be in the range of 1.6 to 8.5 microns with a corresponding Hegman fineness of grind of 4 to 6.5. The size distribution is critical to maximize the distribution of barite and pigment (Guillet and Kriens 1984, Griffiths 1984).

Component		Required Specification
$BaSO_4$		94.0 - 98.5%
SiO_2		1.5 - 2.5%
Al_2O_3		1.2%
Fe_2O_3		0.9%
MnO		0.15%
Moisture content	=	0.10%
Hardness (Mohs scale)	=	3.5
Specific gravity (g/cm^3)	=	4.30
Bulking factor (gals/lb)	=	0.0279
pH	=	4.0 - 7.8
Oil absorption ($cm^3/100g$)	=	11.0 - 12.0
Dry brightness	=	96.0
Refractive index	=	1.64

Table 2-2: Specifications for barite fillers in paint (Prud'homme and Francis 1987a).

2.3.1.4 Price Range

Barite prices are list prices quoted for the North American market. The same system of reporting is used by Energy Mines and Resources Canada. However, there is frequent discounting of list prices for large volume sales and preferred clients.

In September 1988 the list prices for barite recorded in the Chemical Marketing Reporter were:

Barite, dry-ground, southern United States off-colour, coarse, bags in carload lots, f.o.b. mines (a raw product - receiving only primary processing at the mine).	$250 (Cdn.)/tonne
Barite, water-ground, white, bags in carload lots, f.o.b. works (a processed product suitable for well-drilling or other uses).	$360/tonne
Barite, unbleached, extra-fine, pigment grade, carload, f.o.b. works.	$200/tonne
Barium sulfate, United States pharmacopoeia, X-ray diagnosis grade, powder, 25 kilogram bags, 10,000 kilo lots.	$1,600/tonne

In December 1987, the price for barite as reported by Engineering and Mining Journal (Shaw and Boucher 1987) was:

Barite, water ground, 95% $BaSO_4$, 325 mesh, 23 kg bags.	$95-225(Cdn)/tonne

2.3.1.5 Consumption Levels

A recent study estimated that the consumption of barite filler for paint was in the order of 40,000 tonnes per year with 30,000 tonnes per year in the market area for this study (Guillet and Kriens 1984).

A report on Canada's paint industry reported barite consumption of 1984 tonnes in 1983 valued at $840,000 or $423/tonne and representing 0.14% of the total cost of materials and supplies used in the paint manufacture. In the 1979-1983 period Canadian barite consumption fluctuated from 1897 to 2215 tonnes per year. On average 60-80% of the consumption occurred in Ontario, 15-35% in Quebec, 2-5% in British Columbia, 1-2% in Manitoba, and small quantities in Newfoundland, Nova Scotia, and Alberta. No consumption was reported in New Brunswick (Prud'homme and Francis, 1987a).

Comparable statistics for consumption of barite by the paint industry in the U.S. portion of the study area were unavailable. However, section 3.3.4.4 provides a discussion of the location of paint manufacturers in this area.

2.3.2 Plastic Industry

2.3.2.1 Background

According to Siegfried Mandel's Dictionary of Science, "A plastic is a substance made from mixtures of organic materials, capable of being pressed, molded or melted into a desired shape. A binder substance forms the basis of the plastic to which other ingredients such as plasticizers (largely acid esters), dyes, and filler compounds are added to obtain the desired combination of properties including flexibility, softness, heat resistance or others."

Plastics are a material of the Twentieth Century. Even though first significant plastic, (cellulose nitrate or Celluloid), was discovered in 1868 the material remained more a curiosity than a useful product until the development of commercial phenolic resin in 1909. This marked the beginning of the synthetic plastic industry.

The term "plastic" covers a wide range of materials. Chemists and chemical engineers categorize plastics by key characteristics (see Tables 2-3 and 2-4). Thermoset plastics are cured by heat into infusible or insoluble products. Examples include epoxies and phenolic resins, molded into typical products such as a light switch cover, etc. Thermoplastics are those that become soft and pliable when heated. Examples include vinyl, polyethylene and polyester (Austin 1984). Many plastics are polymers containing many simple units of carbon (C), hydrogen (H) and other atoms; a good example is the vinyl family which all have many CH_2 to CH bonds.

Barite is an inert plastic filler. Inert fillers affect the properties of plastics by (Gachter and Muller 1985):

a) increasing density of the material,

b) increasing the modulus of elasticity as well as increasing compressive and flexural strength (stiffness),

c) reducing shrinkage,

d) increasing hardness and improving surface quality,

e) increasing heat deflection temperature and reducing the temperature dependence of mechanical properties,

f) reducing costs.

Active fillers have a more profound effect upon plastics. These materials act upon the plastic resins in three ways:

i) by forming chemical bonds with the plastic,

ii) by forming secondary or primary valence bonds with the resin thereby immobilizing a portion of the resin,

iii) by forming a surface for movement of resin molecules when the plastic is subject to stress.

Thus active fillers change the properties of plastics by (Gachter and Muller 1983):

a) increasing tensile strength and shear strength,

b) increasing the modulus of elasticity and stiffness,

c) increasing the heat deflection temperature and lowering the temperature dependence of mechanical values,

d) lowering shrinkage,

e) improving creep behaviour and the bend-creep modulus and reducing the viscoelastic yield under load.

Active fillers react with the plastic and change the chemico-physical properties of the plastic (strength, abrasion resistance, resilience).

Plastic Type	Trade Names
Thermosetting Resins	
Phenolic resins	Bakelite, Durez, Catalin, Formica, Indur
Amino resins	Plaskon, Beetle, Cymel, Micarta, Melmac
Alkyd resins	Glyptal, Rezyl, Becksol, Dulux
Epoxy resins	Epon, Araldite, Ren, Epocast, Marblette
Polyester (unsaturated) and allyl resins	Aropol, Atlac, Dapon
Silicone resins	Pyrotex, Dow Corning
Polyimides	Vespel, Kapton
Thermoplastic Resins	
Cellulose Derivatives	
Cellulose nitrate	Celluloid, Pyralin, Nitron
Cellulose acetate	Kodapak, Tenite, Plastacele
Cellulose propionates	Forticel, Reed
Cellulose acetate-butyrates	Tenite II, Kodapak II
Ethyl cellulose	Ethocel, Soplasco, Campeo
Polymer Resins	
Acrylate or polyacrylates	Plexiglas, Lucite, Acryloid
Vinyls	Vinylite, Gelva, Butacite, Koroseal, Alvar, PVA
Polyvinylidenes	Saran
Styrenes	Styron, Lustrex, Loalin
Polyamides	Nylon, Zytel, Kevlar, Nomex
Polyethers	Penton, Calcon, Delrin
Polyethylene	Polyethylene, Poly-Eth, Tygothene, Pentothene
Polypropylene	Poly-Pro, Pro-fax
Fluorocarbons	Kel-F, Teflon, Fluorosint
Polyesters	Mylar, Celanex, Ekonol
Polycarbonates	Lexan, Merlon
Polysulfones	Udel, Astrel 360, Victrex, Radel

Table 2-3: Types of resins and plastics, with some common trade names (Austin 1984).

I. Derivative of Natural Products (thermoplastic, except where noted.

- A. Natural resins
  - 1. Fossil and plant resins
  - 2. Rosin
  - 3. Shellac
  - 4. Lignin (thermosetting)
- B. Cellulose derivatives
  - 1. Regenerated cellulose
    - a. Viscose
    - b. Cuprammonium
  - 2. Cellulose esters
    - a. Nitrate
    - b. Acetate
    - c. Propionate
    - d. Mixed esters (nitrate-acetate, acetate-propionate, acetate-butyrate)
  - 3. Cellulose esters
    - a. Methyl
    - b. Ethyl
    - c. Carboxymethyl
- C. Protein derivatives
  - a. Casein-formaldehyde
  - b. Zein (corn protein)-formaldehyde
  - c. Soybean protein-formaldehyde

II. Synthetic Resins Formed by Condensation Polymerization (thermoset, except where noted)

- A. Phenolic resins
  - 1. Phenol-formaldehyde
  - 2. Phenol-furfural
  - 3. Resorcinol-formaldehyde
- B. Amino resins
  - 1. Urea-formaldehyde
  - 2. Melamine-formaldehyde
- C. Polyesters
  - 1. Alkyd
  - 2. Unsaturated or oil-modified alkyds
  - 3. Polycarbonates (thermoplastic)
- D. Polyethers (thermoplastic)
  - 1. Polyformaldehydes
  - 2. Polyglycols
- E. Polyurethanes (thermoplastic under some conditions)
- F. Polyamides (thermoplastic)
- G. Epoxides
- H. Silicone resins (thermoplastic under some conditions)
- I. Ionomers
- J. Polysulfones
- K. Polyimides

III. Synthetic Resins Formed by Addition Polymerization (thermoplastic)

- A. Polyethylene
- B. Polypropylene
- C. Polyisobutylene
- D. Fluorocarbon polymers
- E. Polyvinyl acetate and derivatives
  - 1. Polyvinyl alcohol
  - 2. Acetals
- F. Other vinyl polymers
  - 1. Polyvinyl ethers
  - 2. Divinyl polymers
  - 3. Polyvinyl chloride
- G. Polyvinylidene chloride
- H. Polystyrene
- I. Acrylic polymers

Table 2-4: Classification of commercial resins and plastics by derivation (Austin 1984).

2.3.2.2 Applications

The plastics industry is the second largest consumer of barite fillers. Many of the attributes of barite which make it useful for paint also apply to plastics: inertness, resistance to acids and alkalies, high density, and high brightness. In addition, barite improves the dimensional stability of and provides reinforcement for plastics.

Barite is used in plastics with high apparent density, such as polyvinyl chloride (PVC), polyesters, and polyurethane. The term "apparent density" refers to material which is dense on a molecular basis but appears to have a lower density due to the structure of the material. For example, most plastic are composed of long strings of molecules which are quite dense, but when combined form materials which are quite light due to voids in the material. These materials are commonly used for floor coverings, furniture, bedding, and various automotive products. For sound proofing materials, up to 80% barite is used (Griffiths 1984).

An additional property of barite is that it can be used for radiation shielding as it absorbs gamma rays and X rays (Gachter and Muller, 1983; Guillet and Kriens, 1984; Prud'homme and Francis 1987b).

2.3.2.3 Specifications

Specifications for barite fillers are usually negotiated by the producer and buyer. For plastics, barite should have medium to high brightness; the latter for polyethylene and vinyl. Bleached barite is acceptable.

Particle sizes should be medium to fine. Grade should exceed 95% $BaSO_4$ (Guillet and Kriens 1984).

2.3.2.4 Price Range

See Section 2.3.1.4.

2.3.2.5 Consumption Levels

Estimated North American consumption of barite filler for plastic manufacture was 16,000 tonnes per year for 1980-1985, of which 6,000 tonnes per year was consumed in the study area (Guillet and Kriens 1984).

North America's plastics industry is concentrated on the east coast of the United States (New Jersey, Delaware, Pennsylvania, New York) and the Great Lakes (Ohio, Tennessee, Montreal area, Southwestern Ontario). Thus, although it is difficult to identify the exact pattern of barite consumption in plastics it seems safe to say that most barite is used on the east coast or Great Lakes regions. Section 3.3.3.4 provides data on the consumption within 800 km of New Brunswick.

2.3.3 Rubber

2.3.3.1 Background

Rubber is a material of great economic importance. In the twenty-year period between 1960-1979, rubber consumption increased by 110% in the United States, or 3.8% a year.

Pure rubber originates from either natural or synthetic sources. However, pure rubber is usually not suitable for use as it is very soft, sticky and quickly becomes brittle

through oxidation. The desirable properties of rubber are obtained or enhanced through the use of various rubber-processing chemicals (sulphur, amines, fillers). With these chemicals a rubber material can be manufactured with certain desired physical properties related to plasticity, elasticity, toughness, hardness or softness, abrasion resistance, and impermeability.

The role of fillers in rubber production can be inert or active. Most fillers (clays, coal, barite) are inert and are used to either harden the rubber mixture or dilute the rubber content. Their use often results in a material which is either less tensile, harder or more shape-retentive and less expensive. In addition, some inert fillers are simply used to vary the colour of the material.

Active fillers react with rubber in chemico-physical reactions. Finely divided amorphous materials (carbon black, silica) greatly increase the strength, abrasion resistance and resilience of rubber (Austin, 1984).

2.3.3.2 Applications

Rubber production is the third largest consumer of barite in North America. Use of barite as a filler enhances the elasticity (better cross-linkages), specific gravity (due to barite density) and chemical performance (due to the inertness of barite) of rubber. Products using barite-filled rubber include tires (i.e. the "stripe" in whitewall tires), tire products and various sporting goods (basketballs, core of tennis balls). For sporting goods, barite is used as a weighting agent. (Guillet and Kriens 1984, Griffiths 1984, Prud'homme and Francis 1987c).

2.3.3.3 Specifications

For rubber applications, barite should have high brightness, low abrasiveness, and fine particle size.

2.3.3.4 Price Range

See Section 2.3.1.4

2.3.3.5 Consumption Levels

The estimated North American consumption of barite filler for rubber is 4,000 tonnes per year based upon a 1984 study (Guillet and Kriens). Of that consumption, approximately 2,000 tonnes occurs within the market area of this study.

Statistics on consumption according to geographic area were unavailable. However, it seems safe to assume that barite consumption patterns would be centred in south-western Ontario (Sarnia) and Ohio (Akron). Section 3.3.7.4 provides a discussion of the location of manufacturers of rubber products in the study area.

2.3.4 Other Uses

2.3.4.1 Applications

Barite is often used in carpet backing for automobile carpets as it increases foam density and weight thereby increasing its sound absorption. (See Section 3.3.1.1 for a discussion of the use of fillers in carpet backing).

Barite also contributes chemical resistance and high density to putty, caulks and sealants. Automobile sealants use barite to help deaden sound. (See Section 3.3.6.1 for a discussion of the use of fillers in putty, caulks and sealants).

2.3.4.2 Specifications

For carpet backing, barite should have medium brightness and medium to fine particle size (around 12 micron size).

High brightness, fine particle size and low abrasiveness are required of barite used for putty, caulks, and sealants.

2.3.4.3 Price Range

See Section 2.3.1.4.

2.3.4.4 Consumption Levels

The estimated consumption of barite for carpet backing in North America is 2,000 tonnes per year, 200 tonnes per year within the market area for this study. For putty, caulks, and sealants the respective consumption estimates are 500 tonnes per year and 300 tonnes per year (Guillet and Kriens 1984). As for plastics, most of this material will be manufactured in the Great Lakes and east coast regions.

2.4 Competitive Materials

The high specific weight of barite makes it unique among common non-metallic minerals used as fillers. Thus, in many cases, it has few competitive materials.

However, barite is relatively expensive when compared to other common fillers, thus its use is often price dependant. A good example of substitution is the use of calcium carbonate in paints in place of barite. Even though calcium carbonate has inferior properties it is considerably less expensive.

2.5 Trends and Market Potential

Barite production is very dependent upon the status of the oil and gas exploration industry which has historically represented approximately 65 and 90% of consumption in Canada and the United States respectively. Fillers represent an important but small part of the total.

Paint production is expected to grow, but barite consumption should remain static or fall as barite is displaced by calcium carbonate. High cost of barite filler material appears to be one of the major driving forces toward the substitution trend.

High price is also leading to barite substitution in the plastics industry. However, the unique physical properties and advantages of barite should help it maintain market position in this area. Projected growth and expansion of the plastics industry could eventually result in a moderate increase in consumption.

Modest growth in the order of 2.5 to 3.5 percent is projected for barite demand in filler and extender markets (Boucher and Shaw 1987). This forecast is based largely on expectations of modest growth in automotive and construction sectors.

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3.0 CARBONATES

3.1 Introduction and Overview

Carbonate rocks include both limestone, dolostone and their metamorphic equivalent marble. Limestone is composed predominantly of the mineral calcite ($CaCO_3$), a pure form of calcium carbonate. When magnesium substitutes in part for calcium in calcite, the mineral dolomite ($CaMg(CO_3)_2$) results. In addition to the minerals calcite and dolomite, carbonate rocks consist of varying quantities of several other minerals, the principal ones being various clay minerals and quartz. As the percentage of these deleterious minerals increase in carbonate rocks, their purity in terms of carbonate content decreases. In addition, the relative quantities of calcite and dolomite can vary yielding carbonate rocks such as dolomitic limestone or calcareous dolostone.

Carbonate rocks are mined at numerous North American locations. The majority of these operations produce agricultural lime, cement products, construction aggregate, and other similar low unit value commodities. Some operations also produce low specification, low price fillers as a portion of their total output. These fillers commonly have good chemical characteristics but lack the necessary whiteness for applications where high brightness is required. Low grade industrial carbonate fillers of this nature are utilized in applications such as asphalt shingles where low cost is the most important consideration and colour is not critical.

The use of carbonate and particularly of calcium carbonate for the production of fillers, extenders and whiteners is based primarily upon its relatively low cost and excellent availability. Producers of high grade carbonate fillers tend to limit their production to premium grade products. Other commodities can be produced but typically are regarded as secondary output. Since the specifications for high grade fillers favour high brightness, a very white stone is typically the source material for such operations. This is particularly important for very fine or ultrafine products. In North America, limestone and/or marble is the carbonate of choice for feedstock for high grade fillers. In Europe, however, dolostones having high brightness and the required purity are commonly used. An off-white stone is an acceptable source of raw material for some lower specification products.

Terms such as coarse, medium, fine, very fine, superfine and ultrafine are frequently used in the description of calcium carbonate filler products. However the size limits for these terms tend to be vague and the use of the terms often varies with individual producers. Grade designations for pulverized or ground limestone (and marble) are covered by the American Society for Testing Materials (ASTM), Standard D-1199. Table 3-1 lists the calcium carbonate filler specifications covering each of the four grade classes recognized by ASTM. It should be recognized, however, that each grade covers a wide range and producers often have several products having slightly different specifications within each grade category.

GRADE(ASTM-D-1199)	GRADE I	GRADE I	GRADE II	GRADE II	GRADE II	GRADE III	GRADE III	GRADE IV
PARTICLE SIZE ANALYSIS								
% Retained on 325 Mesh Sieve	0.005	0.01	0.02	0.02	0.0	1.0	1.0	22.0
Particle Size Range (Microns)	0.5-15.0	0.5-13.0	0.5-36.0	1.0-50.0	0.5	8.0	8.0	40.0
Mean Particle Size (Microns)	3.0	6.5	7.0	12.5	13.0	17.5	17.5	36.0
Hegman Grind	6 - 6.25	5 - 5.25	4 - 4.25	3				
PHYSICAL PROPERTIES								
Oil Absorption, ASTM-D-281 (lbs/100 lbs)	14.0-16.0	13.0-15.0	12.0-14.0	10.0-12.5				
Oil Absorption, ASTM-D-1483 (lbs/100 lbs)	15.0-17.0	13.5-15.0	13.0-15.0	11.0-13.0				
Loose Bulk Density (lbs/cu ft)	49.0	59.0	62.0	63.5	64.0	69.5	69.5	74.0
Bulking Value (gal/lbs)	0.0443	0.0443	0.0443	0.0443	0.0443	0.0443	0.0443	0.0443
Specific Gravity	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71
Specific Resistance (ohms)	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
pH	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Hardness (Mohs)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Refractive Index (mean)	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
Dry Brightness (minimum)	96.0	96.0	94.0	93.0	93.0	85.0	93.0	90.0
CHEMICAL COMPOSITION								
% Calcium Carbonate ($CaCO_3$)	98.00%	98.00%	98.00%	98.00%	95.00(min)	95.00(min)	95.00(min)	95.00(min)
% Magnesium Carbonate ($MgCO_3$)	0.60	0.60	0.60	0.60	3.00(max)	3.00(max)	3.00(max)	3.00(max)
% Silica (SiO_2)	0.50	0.50	0.50	0.50	1.00	1.00	1.00	1.00
% Iron Oxide (Fe_2O_3)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
% Alumina (Al_2O_3)	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
% Moisture (H_2O)	0.02	0.02	0.02	0.02	0.02	0.15	0.15	0.15

Table 3-1: Grade designation and typical properties of calcium carbonate fillers (Guillet and Kriens, 1984)

Consumption of calcium carbonate fillers is diverse. Consumption for carpet backing and joint compounds represents nearly 50 percent of the market. However, these market sectors use industrial grade fillers which are regarded as secondary quality due to off-white colour, lower brightness, and a medium to coarse particle size. The balance of the market uses high grade fillers. The plastics industry consumes about 20% and the paint industry about 12%. The paper industry, the putty, caulk and adhesives industries, and the rubber industry each consume about 6%.

3.2 Production of Carbonates

3.2.1 Location and Capacity of Producers

The North American high grade carbonate filler market is dominated by twelve producers with operations at eighteen locations. An additional six producers of industrial grade carbonate fillers are located within or in close proximity to the perimeter of the study area. These producers are listed in Table 3-2 and are located geographically in Figure 3-1.

In Canada, Steep Rock Calcite and Imasco Canada Ltd., of Ontario and British Columbia respectively, produce high grade mineral fillers. Industrial Fillers Ltd., of Quebec and Domtar Chemicals' Lime Division, Beachville Lime Co., Steetley Minerals and E.C. King, all located in Ontario produce industrial grade fillers.

Steep Rock Calcite, a division of Steep Rock Resources Inc., produces a full range of high quality ground calcium carbonate filler products at Perth, Ontario from a white calcitic marble deposit located at Tatlock 40 km north of

Company	Location	Production (tonnes)
Canada		
HIGH GRADE FILLERS		
1. Steep Rock Calcite	Perth, Ont.	> 152,000
2. Imasco Canada Ltd.	Creston, B.C.	n/a
INDUSTRIAL FILLERS		
3. Industrial Fillers Ltd.	Montreal, Que.	90,000
4. Domtar Chemicals	Beachville, Ont.	n/a
5. Beachville Lime Co.	Beachville, Ont.	n/a
6. Steetley Minerals	Dundas, Ont.	n/a
7. E.C. King	Owen Sound, Ont.	n/a
U.S.A.		
HIGH GRADE FILLERS		
8. Atlantic Carbonate Co.	Texas, Md.	n/a
9. Calcium Carbonate Co.	Marble Falls, Tx.	82,000
	Seattle, Wash.	4,500
10. Genstar Stone Products Inc.	Hunt Valley, Md.	168,000
11. Georgia Marble Co.	Dalton, Ga.	609,000
12. Omya Inc.	Proctor, Vt.	181,000
	Lattabra, Calif.	272,000
13. Mississippi Lime Co.	Ste. Genevieve, Mo.	145,000
14. Pfizer Inc.	Adams, Mass.	}
	Lucerne Valley, Calif	} 118,000
15. Sylacauga Calcium Products	Sylacauga, Ala.	106,000
16. Thompson, Weinman and Co.	Sylacauga, Ala.	}
	Cartersville, Ga.	} 206,000
17. White Pigment Co.	Florence, Vt.	}
	New Haven, Vt.	}
	York, Pa.	} 132,000
INDUSTRIAL FILLERS		
18. National Gypsum	York, Pa.	n/a

n/a - not available

Table 3-2: Principal producers of carbonate fillers in North America. See location map - Figure 3-1.

Figure 3-1 Location map of principal producers of carbonate fillers in North America.

the Perth plant. In 1983 production totalled 152,000 tonnes with production of fine grades increasing in that year. In 1987 production of ultrafine slurries was undertaken, in partnership with Georgia Kaolin, through a subsidiary firm called Ontario Carbonate. The level of production is 40-45,000 tonnes per year. MAS Minerals Corp., a subsidiary of Pluess-Staufer AG of Switzerland who are a leading western European producer of fillers, acquired 90.5% of the shares of Steep Rock Resources in 1988.

Imasco Canada Ltd. produces both calcitic and dolomitic fillers at Creston, British Columbia. Production is limited to medium to coarse grades. Production capacity is not known.

Industrial Fillers Ltd. of Montreal produces a range of coarse ground off-white products. Annual capacity is approximately 90,000 tonnes. In Ontario, Domtar's Beachville plant, Beachville Lime's operation in the same community, Steetley Minerals in Dundas, a division of Steetley Industries Ltd. of Hamilton, and E.C. King of Owen Sound, all produce coarse ground industrial grade fillers. Production capacities of these operations are unavailable.

In the United States there are ten major producers of very white high grade fillers. They are the Atlantic Carbonate Co.; Calcium Carbonate Co.; Genstar Stone Products; Georgia Marble Co.; Mississippi Lime Co.; Omya Inc.; Pfizer Inc.; Sylacauga Calcium Products; Thompson, Weinman and Co.; and White Pigment Co.

The Atlantic Carbonate Co. at Texas, Maryland is a joint venture of Genstar Stone Products and Anglo-American Clays, a subsidiary of the English China Clay Co. of

Cornwall, England. The annual production of its plant is not available. Genstar's operation at Hunt Valley, Maryland produced approximately 168,000 tonnes of product in 1983.

The Calcium Carbonate Co., a subsidiary of the J.M. Huber Corp., operates calcium carbonate plants at Marble Falls, Texas and Seattle, Washington. The Texas facility yielded 82,000 tonnes, and the Washington plant 4,500 tonnes in 1983.

The Georgia Marble Co., a division of the Jim Walter Corp., had an annual capacity of 609,000 tonnes of product in 1983. Production originates from quarries at Gantt's Quarry, Alabama and Tate and Whitestone, Georgia and a grinding plant located at Dalton, Georgia.

Omya Inc.'s parent company is Pluess-Staufer AG of Switzerland, who also have indirect control of Steep Rock Calcite of Perth, Ontario. Omya purchased the Vermont Marble Co. in Proctor, Vermont where annual capacity is approximately 181,000 tonnes. Capacity at its Lattabra, California plant is approximately 272,000 tonnes.

The Mississippi Lime Company of Ste. Genevieve, Missouri produces 145,000 tonnes of precipitated calcium carbonate (PCC) per year. The plant, expanded to its current size in 1987, is one of two nondedicated PCC facilities in North America.

Pfizer Inc.'s Minerals Pigments and Metals Division has production facilities at Adams, Massachusetts and Lucerne Valley, California. Annual capacity in 1983 totalled 118,000 tonnes. Pfizer's Adams plant includes the second of two nondedicated PCC facilities in North America, producing

between 9,000 and 18,000 tonnes per year.

Sylacauga Calcium Products, a division of the Moretti-Harrah Marble Co. Inc. produced 106,000 tonnes of product at Sylacauga, Alabama in 1983.

Thompson, Weinman and Co., is a subsidiary of Cyrus Industrial Minerals Co. which is owned by Standard Oil of Indiana. Production originates from Sylacauga, Alabama and Cartersville, Georgia and totalled 206,000 tonnes in 1983.

The White Pigment Co. is a partnership between Thompson, Weinman and Vermont Marble of Omya. Production totalling 132,000 tonnes in 1983 originated from Florence and New Haven, Vermont and York, Pennsylvania.

At least eight producers of slightly off-white, industrial fillers are known in the U.S. The National Gypsum Company is one such producer located within the study area at York, Pennsylvania. Production figures for National are unavailable.

3.2.2 Mining, Processing and Beneficiating Technology

3.2.2.1 Mining

Carbonate rocks are normally mined by surface quarrying. Operating methods are usually similar to conventional quarrying of construction aggregate. However, because of stringent quality requirements, selective quarrying of high purity material is common to avoid zones of unsuitable rock. It is desirable to have a number of working faces to give flexibility to the operation and permit blending where quality variations occur. Adequate

definition of the deposit and its internal variations is a prerequisite for the level of grade control required.

During the site preparation phase of a quarry, complete removal of the overburden is necessary to avoid contamination. Earth moving equipment is employed initially, followed by cleaning of the rock surface using compressed air or similar methods. If the site is elevated and well-drained, hydraulic washing by high pressure hoses can be used for final cleaning.

The quantity of overburden to be removed from the bedrock during site preparation will affect the operation's viability. In most cases the overburden consists only of unconsolidated material. The presence of waste bedrock above the ore adds to site preparation costs. The maximum economic limit of the overburden to ore ratio tends to be site specific and depends upon the economics of the particular operation.

Following site preparation, pit development is undertaken through the establishment of a system of benches. This phase can be simple or complex as dictated by the geology of the deposit. Bench height varies depending on the depth that blast holes can be drilled and the convenient bank height that a power shovel or other loading machine can work. The width of the bench depends on the size of the equipment used to haul the ore and on the room needed for loading. The ore must be drilled, loaded with explosives and blasted prior to removal from the bench. Mining proceeds as the pit is developed by the systematic removal of benches. Run-of-mine rock is passed through primary and secondary crushers and sized in preparation for mill feed.

Large uniform deposits may lend themselves to large-scale contract mining. Steep Rock's quarry at Tatlock, Ontario, for example is worked only for a few weeks each summer, when sufficient crushed marble is stockpiled at the Perth plant for the year's needs.

Underground mining of carbonate rocks is less common but there are a number of underground mines in the United States. In 1981, 129 underground operations produced more than 45 million tonnes of rock. Underground mining is somewhat more costly than surface mining and is utilized only in special circumstances, such as when deep quarrying of a particular deposit has reached its economic limit, or when alternative sources are not available on surface within an economic haulage distance to processing facilities or markets.

Deposits of high purity calcium carbonate, because of their greater scarcity and value, are most likely to be considered for underground mining. White calcitic marble is mined underground at Tate, Georgia, by Georgia Marble Company; at Crab Orchard, Tennessee, by Franklin Limestone Company; at Texas, Maryland, by Atlantic Carbonate; at Danby, Vermont, by Vermont Marble Company and at Mosher, Missouri by Mississippi Lime.

Since deposits of limestone and marble are commonly tabular in shape they are usually underground mined by room and pillar methods. Access is often by horizontal tunneling into a hillside or quarry face, but inclined ramps and vertical shafts are also used.

Few limestone mines are more than 300 m deep and most are less than 100 m. The mines are well ventilated and spacious to accommodate large conventional diesel trucks and loaders. Rooms are at least 5 m high and 10 m wide and may be as high as 25 m and as wide as 15 m. However, roofs higher than 10 m become increasingly difficult to reach for necessary rock sealing and roof-bolting. At least 25 percent of the deposit is left in the mine as pillars to support the roof.

Except where underground workings are accessible to quarry trucks via horizontal or inclined ramps on gradients of about 10 percent, primary crushing is normally carried out before hoisting to surface. In such cases the crushed rock is moved by conveyor to the shaft, or directly to surface plant or stockpile by inclined conveyor in special conveyor ways at about 25 percent grade (4:1 slope).

3.2.2.2 Processing and Beneficiation

Methods used in the processing of limestone for filler applications are dependent on the mineralogical and chemical purity of the raw material and the product quality required by the consuming industries. Since the market within a given geographic area commonly includes a range of potential consumers with varying specifications, processing methods tend to be designed to be capable of producing a broad range of products.

Calcium carbonate fillers are produced from quarried limestone utilizing one of two processes, grinding or precipitation. Traditionally, precipitated calcium carbonate has been an ultrafine, very white, high value product directed towards applications having more demanding

specifications. The development, however, of sophisticated grinding and classification technologies, has opened portions of the ultrafine filler market to certain ground products.

3.2.2.2.1 Grinding

The production of ground calcium carbonate (GCC) begins with primary crushing (Figure 3-2) which is usually accomplished with jaw or gyratory crushers. Impact crushers are used in some instances where the raw material is soft and free of silica.

Electronic colour sorting utilizing automated photoelectric conveyor system scanners have been successfully applied in some cases to remove "off-colour" rock or gangue minerals. It is currently being used in Finland and is under investigation by producers elsewhere.

Secondary crushing is usually accomplished by cone or impact crushers. The equipment selection is based on the nature of the rock to be crushed. Secondary crushers usually operate in closed circuit with vibratory screens to provide properly sized feed for subsequent processing, or to produce granular products for non-filler applications. Autogenous or semi-autogenous milling can be used for secondary processing provided the raw material is amenable to this grinding method. In this type of mill, the rock particles grind together and the abrasion gives the required size reduction. A grinding medium, such as iron balls, is often not required, and the potential for contamination is reduced.

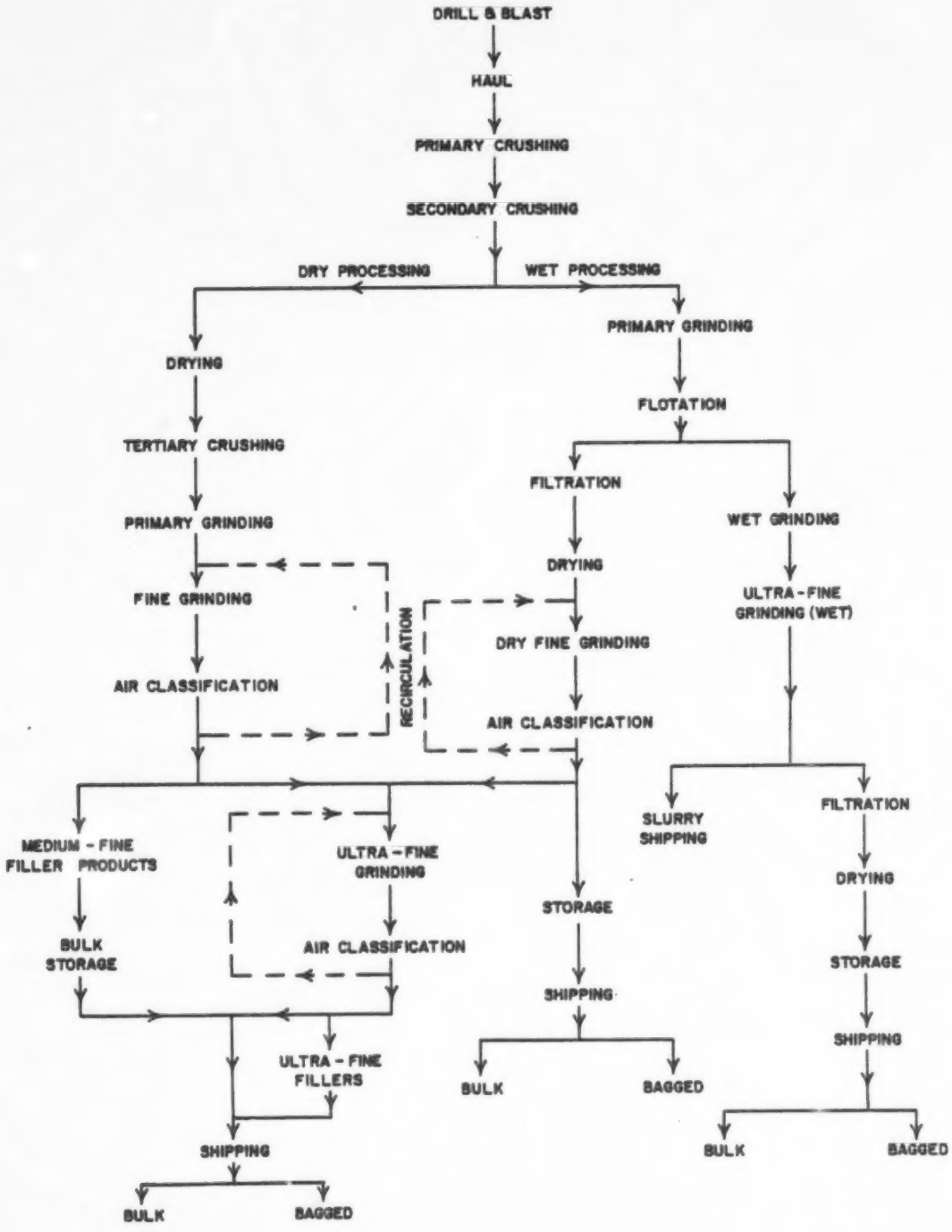

Figure 3-2 Conceptual flowsheet - ground calcium carbonate production, dry or wet processing alternatives (Guillet and Kriens, 1984).

Further processing may consist of a third stage of crushing or grinding. The crushing methods available and the range of suitable equipment are broad and in general are tailored to later processing requirements.

Roll crushers, roller mills, cage mills, rod mills and ball mills may be used, often as pregrinding units, providing feed for a fine grinding circuit or for a froth floatation circuit.

Subsequent processing may include fine grinding and classification. Roller mills are frequently used to produce medium to fine filler products, up to 99% passing 325 mesh (44 micron).

Ball mills, pebble mills and vibratory mills are the principal methods of fine grinding. This type of equipment usually operates in a closed circuit that includes air classifiers, with oversize particles from the classifier returned to the grinding mill for further grinding. The material produced by the classifiers may be the finished products or they may be used as feed to a second stage of classification to produce even finer products. Grinding mills may range from large diameter, short length autogenous mills and conical mills to small diameter, long length tube mills. Some mills have two or more grinding compartments, separated by grates, using progressively smaller size grinding media in successive compartments. Product discharge can be by gravity, or by air sweeping the mill and removing the ground material and conveying the produce-laden air to an air classifier.

The selection of the fine grinding equipment is based both on economic and technical considerations. Conventional

ball or pebble mills are used to grind products ranging from 100 to 325 mesh. Vibratory mills and agitator mills are capable of grinding to even smaller particle sizes. Dry mills can operate in open or closed circuit with air classifiers and cyclones; wet ones with classifying centrifuges.

Air classification allows production of very fine products with a maximum size of 8 microns. Multi-stage classification is often employed to produce a range of fine filler products. In this process, a fine product is produced in the first classifier with the oversize directed to a second classifier to produce the next coarser product. This may be repeated several times.

While it is not common practice as yet, grinding aids may be used in the grinding of carbonate filler. These are in the form of various commercial organic liquids especially prepared for the purpose. The grinding aids prevent formation of micro-agglomerates which may coat the grinding media and mill shell. This condition is often encountered in fine grinding. Grinding aids, if properly selected, can also improve the flow properties of the mineral and the efficiency of air classification.

For certain product applications it is advantageous to coat the individual filler particles with agents such as calcium stearate, stearic acid and titanium bearing compounds. Coating agents, sometimes referred to as coupling agents or surface modifiers, are added to optimize cost/performance benefits of the filler. Calcium carbonate fillers in plastic resins, although excellent resin extenders, do not affect the physical properties of the manufactured product. Surface coatings on calcium carbonate

filler products added to plastic resins enable higher loading levels, reduce melt viscosity, lower power requirements, improve rheological properties and provide improved impact resistance and a greater life expectancy by increasing fatigue resistance properties, increasing durability by minimizing loss of volatiles, and increasing resistance to degeneration caused by ultraviolet rays.

The techniques for particle coating or surface treatment with coupling agents are often proprietary. High speed, high intensity mixers operating in a batch configuration are popular in Europe. High speed pin mills, vibratory mills, disc mills and various other "high shear" mixers are used in North America. In some instances, producers of carbonate fillers contract out their coating or other surface modification treatments to specialists.

Environmental aspects are an important facet of mineral processing. The technology and equipment for dust collection, noise suppression and waste disposal are well developed, so that compliance with environmental regulations can usually be achieved.

3.2.2.2.2 <u>Precipitation</u>

In the manufacture of precipitated calcium carbonates (PCC), limestone is calcined in kilns, bringing about its decomposition into carbon dioxide gas (CO_2) and quicklime (CaO). The kiln gas is then cooled, and in some cases depending upon the quality required, scrubbed. The quicklime is rough screened then slaked with water, under controlled conditions, to form hydrated lime, commonly called milk of lime ($Ca(OH)_2$). In most manufacturing processes, the purity, activity, particle size, concentra-

tion and temperature of the milk of lime have a pronounced affect on the end product. Organic impurities are burnt off in the calcination process and the inorganic impurities are removed by size separations in the slaking process.

Three processes are available for producing precipitated calcium carbonate from milk of lime: the carbonation process, the lime soda process, or the Solvay process.

In the carbonation process, the kiln gas (CO_2) is bubbled through the milk of lime ($Ca(OH)_2$) resulting in the precipitation of calcium carbonate ($CaCO_3$).

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$$

The particle shape and size are a function of the reaction rate. The temperature and the concentration of raw materials control the reaction rate. An elevated temperature or a low concentration of raw material represent less favourable conditions for precipitation, i.e. favourable to remain in solution, and yields a smaller particle size. Carbonation is the favoured process for the production of premium grade precipitated calcium carbonate.

In the lime soda process, sodium carbonate (Na_2CO_3) and milk of lime ($Ca(OH)_2$) are reacted to produce sodium hydroxide (NaOH) and calcium carbonate ($CaCO_3$).

$$Ca(OH)_2 + Na_2CO_3 = CaCO_3 + 2NaOH$$

The physical properties of the two reaction products are governed by the reaction conditions. The kinetics of

the reaction are such that the particle size of one product is the inverse of the other under any given set of reaction conditions. Since the process is used primarily for the production of sodium hydroxide (caustic soda), the calcium carbonate which is precipitated typically has a coarse particle size. The reaction conditions can be regulated to give a uniform, fine-particle-size, precipitated calcium carbonate, but not without some sacrifice in the efficiency of caustic soda recovery.

The Solvay process has been the principal source of sodium carbonate (Na_2CO_3) in North America. The process yields precipitated calcium carbonate ($CaCO_3$) as a co-product with sodium carbonate in accordance with the following reactions:

salt		ammonium hydroxide		ammonium chloride		sodium hydroxide
$NaCl$	+	NH_4OH	=	NH_4Cl	+	$NaOH$
sodium hydroxide		carbon dioxide		sodium bicarbonate		
$NaOH$	+	CO_2	=	$NaHCO_3$		
sodium bicarbonate		sodium carbonate		water		carbon dioxide
$2NaHCO_3$	=	Na_2CO_3	+	H_2O	+	CO_2
ammonium chloride		milk of lime		calcium chloride		ammonium hydroxide
NH_4Cl	+	$Ca(OH)_2$	=	$CaCl_2$	+	$2NH_4OH$
calcium chloride		sodium carbonate		salt		calcium carbonate
$CaCl_2$	+	Na_2CO_3	=	$2NaCl$	+	$CaCO_3$

The precipitation process can be controlled by varying constituent addition times, agitation rates and reaction temperatures. However, this process has declined in use due to the availability of high quality natural sodium carbonate

(trona), high energy costs, and environmental problems associated with salt disposal.

In some instances, paper mills produce calcium carbonates as a by-product of the causticization of soda pulp liquors. Before this calcium carbonate can be used in coating, it is necessary to neutralize its alkali content by treatment with carbon dioxide, acids, or salts, and to grind it to reduce its particle size. In addition, the product must be classified to remove grit. If it is made directly from sulfate pulp liquors, it is bleached to improve its colour.

In all of the above methods of manufacture, the quality of the final product is dependent upon the selection and handling of the raw materials. All suspended impurities present in the raw materials will tend to be precipitated out with the calcium carbonate. Variation in the concentration and temperature of reactants will change the reaction conditions, thereby causing variation in the physical product precipitated. While these processes appear simple, they must be carefully controlled to obtain a uniform and bright final product.

There are presently two North American operations which produce PCC for non-dedicated markets (i.e. product is not allocated (or dedicated) to a specific user). Pfizer Inc. operates a facility at Adams, Massachusetts with a reported annual capacity of 9,000 to 18,000 tonnes per year. The Mississippi Lime Co. operation at St. Genevieve, Mo. has a reported production of 145,000 tonnes. PCC is also produced in so called "portable" or satellite facilities. Production from these units is usually "dedicated" to a single user. Typically a unit is constructed to provide supply to a paper

mill or similar operation.

PCC consumption and production is also discussed in Sections 3.3.5 and 3.6.

3.3 Utilization and Consumption

The bulk of the North American calcium carbonate filler market is comprised of seven major product sectors. Two products, carpet backing and joint compounds, make-up approximately 50% of the market and utilize industrial grade fillers as opposed to the high grade fillers utilized by the balance of the market sectors. In 1983 the North American market for ground calcium carbonate totalled 1,885,000 tonnes, its distribution amongst the various sectors is presented in Table 3-3.

Market Sector	(000 tonnes)	%
carpet backing	476	25
joint compounds	444	24
plastics	385	20
paint	222	12
paper	136	7
putty, caulks, adhesives and sealants	113	6
rubber	109	6
	1,885	100

Table 3-3: North American ground calcium carbonate (GCC) markets (North, 1985).

Data for the levels of precipitated calcium carbonate production are more difficult to obtain. Production capacity of the operations of Pfizer Inc. and Mississippi Lime Co. totals between 154,000 and 163,000 tonnes per year. Consumption is primarily for applications which require fine

particle size and high whiteness such as paper, particularly paper coatings, and plastics. Since production from "portable" PCC facilities typically is supplied to a captive market, levels of production are not publicly available.

3.3.1. Carpet Backing

3.3.1.1. Applications

Carpet backing is manufactured from latex rubber. This use is the single largest volume application for calcium carbonate fillers and requires product specifications separate from other rubber filler applications. The filler, usually calcium carbonate, provides body and weight to the carpet backing.

High level loadings are possible, as much as 500 parts of filler for each 100 parts of latex.

3.3.1.2 Specifications

High quality white and lower quality off-white grades of calcium carbonate fillers are used in carpet backing, often in conjunction with aluminum hydrate. Aluminum hydrate is added to achieve fire retardancy and smoke suppression.

Medium and coarse grained products are used in carpet backing, depending upon the type of latex system used and/or the type and quality of carpet to be manufactured. These products range from 99.5 percent passing a 325 mesh sieve (45 microns) to 10 percent retained on a 200 mesh sieve (75 microns).

The specifications for the calcium carbonate filler product currently used by the Crossley Karastan Carpet Mill in Truro, Nova Scotia are listed in Table 3-4.

3.3.1.3 Price Range

Calcium carbonate fillers used in carpet backing are low cost products. They are less sophisticated products, with the major requirements being low oil absorption and a degree of brightness in the order of 90 on the GE scale. Generally the products required are sold in the $25 to $65 per tonne range. Crossley and Karastan's cost is $55 per tonne delivered to their Truro, Nova Scotia plant site (Davis, 1987).

Product: Pulpro 5
Manufacturer: Industrial Fillers Ltd.

Physical Properties:	
dry brightness	90
refraction index	1.60
specific gravity	2.71
oil absorption (ASTM D281-31)	12
pH (sat. soln.)	10
moisture bulk density	0.5 g/cc
packed bulk density	1.2 g/cc
Particle Size:	
% retained on 325 mesh	trace
top size	20 microns
mean	5 microns
Chemical Analysis:	
$CaCO_3$	96%
$MgCO_3$	2%
acid insolubles	4%

Table 3-4: **Specifications for Calcium Carbonate Fillers Used by Crossley Karastan Carpet Mills Ltd., Truro, N.S. (Davis, 1987).**

3.3.1.4 Consumption Levels

Carpet backing is the largest volume application for calcium carbonate fillers in North America. The carpet industry in the United States, however, is concentrated mainly in the southeast close to the major filler producers in Georgia and Alabama. Within the U.S. portion of the study area carpet production is limited to only a few producers. In Canada, carpet manufacturing is concentrated in Ontario and Quebec. The bulk of the manufacturing in Ontario is outside the study area. Production statistics suggest that carpet backing consumes less than 50,000 tonnes of calcium carbonate annually within the study area. The Crossley Karastan Carpet Mill in Truro, Nova Scotia, the only Atlantic Canada manufacturer of carpet backing, consumes approximately 1600 tonnes of calcium carbonate annually (Davis, 1987).

3.3.2 Joint Compounds

3.3.2.1 Applications

Ground calcium carbonate fillers are used in joint cements used to seal and finish joints in dry-wall board panels. Calcium carbonate content of the joint compounds can be as high as 80 percent by weight.

3.3.2.2 Specifications

The calcium carbonate fillers used in joint compounds typically are 90 to 99 percent passing 325 mesh (45 microns) but coarser 200 mesh (75 microns) products are also used.

While colour is important, of greater importance are the application characteristics of the joint cements. Since these products are applied with applicator knives, joint cements must have good application characteristics. They must not sag on vertical surfaces, or crack during drying. Sanding properties and the colour of the joint cement after drying are also important considerations. Slightly off-white products can be used. Blending white, high quality grades with low cost off-white or slightly gray limestone fillers can sometimes achieve the desired colour quality. One of the prime considerations in selecting a filler for joint cement is its delivered cost.

3.3.2.3 Price Range

Calcium carbonate fillers for joint cements are sold in both bulk and bags. The average f.o.b. plant price in 1983 of bulk shipments in northeastern North America ranged from $50 per tonne for high quality white fillers to less than $35 per tonne for the off-white filler grades.

3.3.2.4 Consumption Levels

The study area is located close to and indeed includes portions of the most heavily populated areas on the continent. This concentration of population is the natural base for a large construction industry utilizing among other products, joint compounds.

The annual North American consumption of calcium carbonate for the manufacture of joint compounds has been placed at approximately 444,000 tonnes. Based upon a 1986 Canadian census and a 1985 United States census, the study area includes approximately 26% of the population of North

America suggesting potential consumption of calcium carbonate for the manufacture of joint compounds in the study area is in excess of 100,000 tonnes.

3.3.3 Plastic Industry

3.3.3.1 Applications

The prime use of calcium carbonate fillers in plastics is as a resin extender. Lower cost in relation to resins and several other filler materials is a major factor. Although some fillers, such as barite, act as reinforcing agents in plastics, calcium carbonate, in its natural state, has no reinforcing properties. Surface coatings and coupling agents can alter its reinforcing properties, but such agents have not yet been used extensively. Calcium carbonate, when used in its ultrafine size ranges, improves scratch resistance and surface reflectance, strengthens impact resistance and improves cold flow properties (See Section 2.3.2.1 for a background discussion on plastics and the use of fillers in the plastic industry).

The major applications for calcium carbonate fillers are in polyvinyl chloride (PVC) and polyester. Approximately 65% of the calcium carbonate fillers used in plastics are used in PVC whereas 30% are used in polyesters. The remaining 5% are used in polypropylenes, polyurethanes, acrylonitrile butadiene styrene (ABS) and phenolics.

Polyvinyl chloride is a thermoplastic, that is, it holds its shape at normal use temperatures but being heat-sensitive, can be deformed and usually reclaimed and reused. PVC includes both flexible types such as calendered vinyl

used for upholstery and rigid types used for pipe, mouldings, construction siding and flooring tile.

Polyesters are thermoset plastics which once polymerized cannot be reshaped or reclaimed. There are two moulding techniques applied to polyesters - press and injection; and two methods of manufacturing mixtures in preparation for moulding - one referred to as sheet moulding compound (SMC) and the other as bulk moulding compound (BMC). SMC is the more efficient technique while BMC permits higher filler loading. Glass-reinforced polyesters have been the fastest growing branch of the polyester market over the past two decades, with the automotive market taking approximately 75% of the polyester consumed. Other polyester products include microwave cookware and housings for personal computers and typewriters.

Polypropylene is traditionally talc-filled but calcium carbonate at a 40-50% loading level will improve impact resistance to the point that it becomes competitive with ABS (acrylonitrile butadiene styrene) in performance but at a lower cost. Increased use of polypropylene in the manufacture of automobile body parts has begun to develop in the last half decade.

3.3.3.2 Specifications

The objective of the plastic producer or compounder is to reduce resin cost as well as overall production costs. Calcium carbonate fillers therefore should not have an adverse affect on equipment performance or cause excessive wear. Specifications for average particle size for the various plastics applications are listed on Table 3-5.

Polymer	Filler Level Parts/100 Parts of Resin	Particle Size Microns
PVC - flexible	20-60	3-13
- floor tile	80-400	74
- plastisols & organisols	20-100	range
- rigid	1-40	1-3
Polyester - SMC	200	3-6
- BMC	250	3-6
- marine	175-200	3-5
Polypropylene	43-67	1-3

Table 3-5: Calcium carbonate filler loading levels and specifications for average particle size and various plastics applications (Guillet and Kriens, 1984).

3.3.3.3 Price Ranges

The similarity in product grade required by the bulk of the plastics industry of calcium carbonate fillers dictates that prices paid are similar to those paid by the paper industry for dry product. Surface treated products are usually custom manufactured fine or ultrafine products that command premium prices. The prices commanded by the various grades of calcium carbonate utilized by the plastics industry are listed on Table 3-6.

3.3.3.4 Consumption Levels

Plastics were, in 1985, and appear to remain, the largest volume user of fine ground calcium carbonate products.

Grade	Cost $Can/tonne (f.o.b. plant)
dry, 9-17 microns, bags and bulk	70-130
dry, 4-7 microns, bags and bulk	100-145
dry, 0.5-4 microns, bags and bulk	175-240
treated, 2-3 microns	240
treated, 1 micron	325
treated, PCC, 0.5 microns	460
PCC, 0.5 microns	300-310
PCC, 0.05-0.5 microns	775

Table 3-6: Price of calcium carbonate filler grades used by the plastics industry (Chemical Marketing Reporter, 1988).

In the Canadian sector of the study area, plastics consume in excess of 3800 tonnes of calcium carbonate fillers. Consumption by province is given in Table 3-7. The number of plants in each province is also shown in the table (see also Figure 1-3).

	Nfld.	N.S.	P.E.I.	N.B.	Que.	Ont.
Year	'85	'87	'85	'85	'85	'85
No. of Plants	3	9	1	13	279	54
Tonnes Utilized	0	>65*	0	12	>936	>2,800

*65 tonnes known to be treated

Sources: 1985 utilization figures - Prud'homme and Francis (1987)
1987 utilization figure - Davis (1987)
No. of plants - Statistics Canada (1983)

Table 3-7: Calcium carbonate filler consumption by the plastics industry in the Canadian sector of the study area.

Available statistics detailing the consumption of calcium carbonate fillers by the plastics industry in the United States do not permit the breakdown of national consumption figures as readily as do Canadian statistics. The U.S. figures provide data (Table 3-8) relevant to the location by state (see also Figure 1-3) and the size of the potential market for calcium carbonate fillers in the plastics industry. The size of the potential market is quantified by quoting the number of firms manufacturing products which may contain calcium carbonate fillers and the value of shipments made by those firms. The statistics, due to their method of compilation, overlap slightly with those quoted for the rubber industry with the result that the figures quoted in Table 3-8 are inflated somewhat from pure plastics industry figures.

The study area includes 27.9% of the U.S. plastics industry, in terms of number of firms in production. These firms shi; 25.7% of the total value of plastics products produced in the U.S. Within the study area, the states of Massachusetts, New Jersey, New York and Pennsylvania account for the bulk of the production. Within any state listed and indeed nationally, manufacturers of miscellaneous plastic products (Standard Industrial Classification (SIC) No. 3079) dominate the industry. This is to be expected given the broad range of products covered within this classification.

3.3.4 Paint Industry

3.3.4.1 Applications

Calcium carbonate is used as pigment extender in interior and exterior oil (alkyd), acrylic (plastic resin) and latex (water)-based paints. The utilization of calcium

State/Commodity	No. of Firms	Percent of National Total	Value of Shipments ($x10^6$)	Percent of National Total
Connecticut				
rubber and plastic footwear SIC 3021	--	--	--	--
rubber and plastic hose and belting SIC 3041	4	2.5	W	W
miscellaneous plastic products SIC 3079	218	1.9	699.5	1.9
insulated wire and cable SIC 3357	37	8.4	455.2	5.5
hard surface floor covering SIC 3996	--	--	--	--
automotive and apparel trim SIC 2396	--	--	--	--
State Total	259	2.0	>1154.7	2.3
Delaware				
rubber and plastic footwear SIC 3021	--	--	--	--
rubber and plastic hose and belting SIC 3041	--	--	--	--
miscellaneous plastic products SIC 3079	34	0.3	W	W
insulated wire and cable SIC 3357	2	0.5	W	W
hard surface floor covering SIC 3996	--	--	--	--
automotive and apparel trim SIC 2396	--	--	--	--
State Total	36	0.3	W	W
Maine				
rubber and plastic footwear SIC 3021	5	7.7	W	W
rubber and plastic hose and belting SIC 3041	--	--	--	--
miscellaneous plastic products SIC 3079	29	0.3	190.8	0.5
insulated wire and cable SIC 3357	--	--	--	--
hard surface floor covering SIC 3996	--	--	--	--
automotive and apparel trim SIC 2396	--	--	--	--
State Total	34	0.3	>190.8	>0.4

Table 3-8: **Number of manufacturers and value of shipment of plastic products in the United States sector of the study area.**

State/Commodity	No. of Firms	Percent of National Total	Value of Shipments ($x10^6$)	Percent of National Total
Massachusetts				
rubber and plastic footwear SIC 3021	4	6.2	W	W
rubber and plastic hose and belting SIC 3041	4	2.5	W	W
miscellaneous plastic products SIC 3079	512	4.4	1,770.7	4.8
insulated wire and cable SIC 3357	40	9.1	440.9	5.4
hard surface floor covering SIC 3996	--	--	--	--
automotive and apparel trim SIC 2396	26	3.2	73.5	3.5
State Total	586	4.5	>2,285.1	>4.5
New Hampshire				
rubber and plastic footwear SIC 3021	4	6.2	W	W
rubber and plastic hose and belting SIC 3041	--	--	--	--
miscellaneous plastic products SIC 3079	61	0.5	345.7	0.9
insulated wire and cable SIC 3357	5	1.1	W	W
hard surface floor covering SIC 3996	--	--	--	--
automotive and apparel trim SIC 2396	--	--	--	--
State Total	70	0.5	>345.7	>0.7
New Jersey				
rubber and plastic footwear SIC 3021	4	6.2	W	W
rubber and plastic hose and belting SIC 3041	13	8.0	59.1	3.0
miscellaneous plastic products SIC 3079	659	5.7	2,249.3	6.1
insulated wire and cable SIC 3357	25	5.7	385.1	4.7
hard surface floor covering SIC 3996	1	5.9	W	W
automotive and apparel trim SIC 2396	55	6.7	41.7	2.0
State Total	757	5.8	>2,735.2	>5.4

Table 3-8: Number of manufacturers and value of shipment of plastic products in the United States sector of the study area. (continued)

State/Commodity	No. of Firms	Percent of National Total	Value of Shipments ($x10^6$)	Percent of National Total
New York				
rubber and plastic footwear SIC 3021	3	4.6	w	w
rubber and plastic hose and belting SIC 3041	5	3.1	w	w
miscellaneous plastic products SIC 3079	820	7.0	1,978.9	5.4
insulated wire and cable SIC 3357	39	8.8	705.7	8.6
hard surface floor covering SIC 3996	4	23.5	w	w
automotive and apparel trim SIC 2396	258	31.2	223.0	10.5
State Total	1,129	8.6	>2,907.6	>5.7
Pennsylvania				
rubber and plastic footwear SIC 3021	8	12.3	76.3	10.8
rubber and plastic hose and belting SIC 3041	6	3.7	31.1	1.6
miscellaneous plastic products SIC 3079	568	4.9	2,083.0	5.6
insulated wire and cable SIC 3357	17	3.9	293.6	3.6
hard surface floor covering SIC 3996	2	11.8	w	w
automotive and apparel trim SIC 2396	35	4.2	34.8	1.6
State Total	636	4.8	>2,518.8	>5.0
Rhode Island				
rubber and plastic footwear SIC 3021	--	--	--	--
rubber and plastic hose and belting SIC 3041	--	--	--	--
miscellaneous plastic products SIC 3079	104	0.9	373.5	1.0
insulated wire and cable SIC 3357	17	3.9	514.2	6.3
hard surface floor covering SIC 3996	--	--	--	--
automotive and apparel trim SIC 2396	--	--	--	--
State Total	121	0.9	887.7	1.8

Table 3-8: Number of manufacturers and value of shipment of plastic products in the United States sector of the study area. (continued)

State/Commodity	No. of Firms	Percent of National Total	Value of Shipments ($x10^6$)	Percent of National Total
Vermont				
rubber and plastic footwear SIC 3021	--	--	--	--
rubber and plastic hose and belting SIC 3041	--	--	--	--
miscellaneous plastic products SIC 3079	32	0.3	w	w
insulated wire and cable SIC 3357	7	1.6	w	w
hard surface floor covering SIC 3996	--	--	--	--
automotive and apparel trim SIC 2396	--	--	--	--
State Total	39	0.3	w	w
United States Sector of Study Area Totals				
rubber and plastic footwear SIC 3021	28	43.2	>76.3	>10.8
rubber and plastic hose and belting SIC 3041	32	19.8	>90.2	>4.6
miscellaneous plastic products SIC 3079	3,037	26.2	>9,691.4	>26.2
insulated wire and cable SIC 3357	189	43.0	>2,794.7	34.1
hard surface floor covering SIC 3996	7	41.2	w	w
automotive and apparel trim SIC 2396	374	45.3	373.0	17.5
State Totals	3,667	27.9	>13,025.6	>25.7
National Totals				
rubber and plastic footwear SIC 3021	65	0.5	706.2	1.4
rubber and plastic hose and belting SIC 3041	163	1.2	1,963.6	3.9
miscellaneous plastic products SIC 3079	11,653	88.5	37,009.0	73.1
insulated wire and cable SIC 3357	441	3.3	8,224.5	16.2
hard surface floor covering SIC 3996	17	0.1	604.1	1.2
automotive and apparel trim SIC 2396	826	6.3	2,130.2	4.2
Total	13,165	99.9	50,637.6	100

SIC - Standard Industrial Classification #
$ - United States Dollar
w - withheld

Source: 1982 Census of Manufacturers, United States Department of Commerce.

Table 3-8: Number of manufacturers and value of shipment of plastic products in the United States sector of the study area. (continued)

carbonate fillers has been enhanced by the wide acceptance of water based paints in the North American market. Limestone is hydrophylic, that is, physically compatible with water and can therefore be used with water. Talc, another commonly used mineral filler in paint, is naturally hydrophobic, will not wet and is therefore incompatible with water based paints (See section 2.3.1.1 for a discussion of the use of fillers in paint).

Calcium carbonate fillers are relatively low cost, have good brightness levels and controlled particle size distribution. They are used primarily in interior flat and exterior house paints. Ground calcium carbonate has good spreading properties, good weathering characteristics and does not interfere with the surface protection features of the paint base.

3.3.4.2 Specifications

Paint manufacturers select extenders for use in their products with particular reference to: oil absorption, fineness (as measured on the Hegman scale), particle size distribution, whiteness (brightness), freedom from abrasive components (i.e. silica), pH (in water slurry), water solubility, chemical composition and bulk density.

Oil absorption is a very critical consideration. A carbonate extender with otherwise equivalent properties but exhibiting a lower oil absorption than competing extenders is of special interest. Such an extender may permit higher loadings of the extender while still achieving a paint with equal or better properties but at a lower manufactured cost.

Lower oil absorption can be achieved by modifying the particle size distribution of the carbonate extender in such a way as to achieve "optimum packing density" i.e. a particle size distribution with a minimum amount of void spaces.

Coarser sized carbonate extenders are commonly used in production of flat (low gloss) paint, while the finer carbonate extenders are used to produce semi-gloss or glossy paints.

The level of addition of carbonate extender varies for flat or glossy paint. Loading levels up to three pounds per gallon are used in flat or semi-gloss paints where as up to one pound is used in glossy paints. Similar loading levels apply to alkyd paints but also vary with resin type in addition to the desired finish which is sought.

The most common carbonate extenders used by the paint industry have the following particle sizes:

45 microns, maximum size, Hegman 4 - Grade II
20 microns, maximum size, Hegman 5 - Grade I
12 microns, maximum size, Hegman 6 - Grade I
8 microns, maximum size, Hegman 7 - Grade I

Superfine calcium carbonates are now being used or evaluated as substitutes for calcined kaolin clay. Calcined kaolin is used in certain paints as a "spacer" for the prime pigment, titanium dioxide (TiO_2). The superfine carbonate fillers typically have a lower oil absorption than calcined kaolin clays, thus allowing higher loadings than calcined kaolin. These new type fillers, which also find applications in plastics and paper, have a maximum size of

approximately 4 microns and a 0.8 micron average particle size and are available in natural or coated form; the latter types for use in plastics applications.

Paints containing coarser carbonate extenders are used in architectural type coatings, such as coating systems for concrete blocks. Such paints are commonly referred to as block sealers. Coarse grade carbonates are also used in textural paints to create a stucco type finish. These carbonate extenders are of a coarse granular type ranging from 2 millimeters downward in size.

In general, the paint chemist will look for a carbonate extender which, when incorporated in a given paint formulation, will provide paint with properties equal to or better than paints made with the standard extender. Most paint manufacturers obtain their carbonate extenders from several sources.

3.3.4.3 Price Ranges

Paint manufacturers in Atlantic Canada indicate the delivered cost for calcium carbonate extenders ranges from $63 to $330 per tonne (Davis 1987). The range is due to variation in extender specifications. The lower value is for coarser, lower brightness products used in traffic (highway) paints. The higher value is for fine (2.5 microns, mean size; 0.5 to 10 micron range), high brightness (95 to 96%) products used in both interior and exterior building paints.

3.3.4.4 Consumption Levels

The paint industry is the second largest consuming industry, by value, after paper of mineral fillers in North America. Approximately one-third of those fillers used in paints consist of calcium carbonate.

In the Canadian sector of the study area, paints consume approximately 13,700 tonnes of calcium carbonate fillers annually. Consumption by province is given in Table 3-9. The number of plants in each province is also given in the table (See also Figure 1-4).

	Nfld.	N.S.	P.E.I.	N.B.	Que.	Ont.
Year	'87	'87	'87	'87	'83	'83
No. of Plants	1	1	1	1	10	22
Tonnes Utilized	na	300	55	18-24	2843	10802

Sources: 1983 figures - Prud'homme and Frances (1987)
1987 figures - Davis (1987)

Table 3-9: Calcium carbonate filler consumption by the paint industry in the Canadian sector of the study area.

Similar to plastics, available statistics detailing the consumption trends of calcium carbonate fillers by the paint industry in the United States do not permit the breakdown of national consumption figures as readily as Canadian statistics. The size of the potential U.S. market is quantified (Table 3-10) by quoting the number of firms manufacturing products which may contain calcium carbonate fillers and the value of shipments made by those firms. The

number of firms in each state is illustrated in Figure 1-4.

Examination of the figures quoted on Table 3-10 indicate that 344 firms, or 55.3% of the total number of manufacturers of paint and allied products in the United States are located within the U.S. sector of the study area. These firms shipped products valued, in 1982, at $U.S.1,633.8 million or 17.8% of the U.S. total. These figures suggest a disproportionate number of small manufacturers in the study area which would no doubt affect the costs in servicing this market. In the U.S., ten leading firms control in excess of 40% of the national market with one firm (Sherwin-Williams) holding 10.6% of the market.

3.3.5 Paper Industry

3.3.5.1 Applications

Calcium carbonate in paper manufacturing is used either as a filler or a coating. In North America, calcium carbonate filler is second only to kaolin in terms of quantities consumed. As a coating, it is third behind kaolin and titanium dioxide. Precipitated calcium carbonate has been preferentially used in paper manufacturing for many years but a shortage in the 1970's resulted in producers of ground product obtaining a foothold in the industry.

In preparation for paper manufacturing, wood pulp and various additives are mixed in a process called beating. This achieves the necessary mixing and blending of the constituents and modifies their fibre structure to yield as widely different products as blotting paper or greaseproof paper. Catagories of additives include sizing agents,

fillers, dyestuffs, and pigments. The sizing agent used actively contributes to the chemistry of the manufacturing process and has a direct bearing upon what filler which can be used. Calcium carbonate can be used as a filler only in papers manufactured by the alkaline or basic sizing process

	No. of Firms	% of National Total	Value of Shipments ($x10^6)	% of National Total
Connecticut	18	2.9	$ 50.80	0.6
Delaware	--	--	--	--
Maine	--	--	--	--
Massachusetts	48	7.7	$ 201.90	2.2
New Hampshire	--	--	--	--
New Jersey	122	19.6	$ 707.60	7.7
New York	98	15.8	$ 267.00	2.9
Pennsylvania	58	9.3	$ 406.50	4.4
Rhode Island	--	--	--	--
Vermont	--	--	--	--
U.S. Sector of Study				
Area Totals	344	55.3	$1,633.80	17.8
National Totals	622	100.0	$9,162.10	100.0

$ - U.S. Dollar

Source - 1982 Census of Manufacturers, U.S. Department of Commerce

Table 3-10: Number of manufacturers and value of shipments of paint and allied products (SIC 2851) in the U.S. sector of the study area.

or in unsized papers. Archival quality papers for such uses as art work must be alkaline since they are much less prone to oxidation and degeneration than acid papers. For papers using acid sizing, calcium carbonate is unsuitable as it reacts in the acid paper. The bulk of the newsprint

manufactured in North America is made in an acidic medium. Dyes and pigments on the other hand are passive ingredients contributing only to colour of the final product. The function of sizing is to render paper resistant to a greater or lesser extent to water penetration. Unsized paper behaves like blotting paper and cannot be effectively written on with water based inks. The sizing agent, commonly rosin, is added to the pulp in solution and fixed to the fibers by the addition of aluminum sulphate, known as papermaker's alum, which causes the rosin to precipitate on the fibers in an extremely fine grained state. These very fine rosin particles adhere to the fibers and form a water resistant covering. The use of aluminum sulphate renders the process environment acidic under which conditions calcium carbonate is unstable and will chemically breakdown. As a result, only inert mineral fillers such as kaolin are compatible with an acidic paper making process.

Synthetic sizing agents have gained increasing popularity in the paper making process in recent years since they do not require the addition of the fixing agent aluminum sulphate. The first synthetic sizing agents used were alkyl ketene dimers prepared from long chain fatty acids but more recently succinic anhydride sizing agents have been introduced. The use of these sizing agents, as opposed to rosin-alum, yields a process environment which is alkaline and therefore compatible with calcium carbonate fillers. The use of ultrafine grades of calcium carbonate in alkaline sized paper yields a stronger grade of paper than that produced by an acidic process, thus permitting higher filler loading levels which result in less wood filler per unit area and decreased manufacturing costs.

The acidic paper manufacturing process is entrenched in the North American industry. The vast majority of the mills are acidic and their staffs are familiar and comfortable with the process. There is a reluctance to convert existing mills to an alkaline process given the cost in terms of capital, lost production time and reduced efficiency during the phase-in of the new process. As a result, even though theoretically there are distinct cost and technical benefits to using an alkaline paper-making process with calcium carbonate fillers, conversion and construction of paper mills using the alkaline process has been well below expectation. This slow acceptance is in marked contrast to Europe where alkaline paper-making has been well-accepted and practiced for many years.

The use of calcium carbonate for paper coating is not bound by the chemistry of the manufacturing process as is its use as a filler. However, in North America, kaolin accounts for up to 80% of the coatings used, followed by titanium dioxide, and calcium carbonate, and a host of other coatings aimed at specialized markets. Kaolin, titanium dioxide and calcium carbonate coatings all contribute to whiteness, improve ink receptivity and surface smoothness.

The amount of carbonate filler used in paper is dependent on the type of paper produced and whether the paper is to be coated or uncoated. Typical filler levels in uncoated paper range from 5 to 15 weight percent of the finished product, while the filler level in coated papers is usually 3 to 9 percent. Paper coatings account for 20 to 30 percent of the weight of coated paper.

Several paper mills in North America are large consumers of precipitated calcium carbonate (PCC) and have PCC manufacturing plants on-site. Production from these plants typically is "dedicated" i.e. used by a single consumer. These plants are commonly constructed and operated under contract with a leading PCC manufacturer. Pfizer operates such units at Consolidated Paper Company's mill in Wisconsin Rapids, Wisconsin and at International Paper Company's mill in Ticonderoga, New York. Other units are under construction for the Northwest Paper Division of Potlatch Corporation in Cloquet, Minnesota and for Hammermill Paper Company at Eric, Pennsylvania. Pfizer has recently (May, 1988) announced plans to construct an additional plant at Mead Paper's Chillicothe, Ohio mill. Their units usually feed slurried product by pipeline directly into the paper mill ensuring immediate product availability and low shipping costs.

3.3.5.2 Specifications

The requirements of calcium carbonate fillers and coatings for paper manufacturing are stringent. Only products generally classed as being ultrafine are used. A product with an average particle size of 1.5 to 2.0 microns is used as a filler, whereas coatings require a product with an average particle size of 0.6 to 0.8 microns. Particle size distribution is also a factor in product acceptability. High brightness, in the range of 92 GE brightness or better, is a necessity. Abrasiveness is detrimental to paper making machines so low abrasion characteristics are required. Rheological properties (viscosity in slurry) are important to application techniques since agglomeration will yield inconsistencies in the resultant paper.

3.3.5.3 Price Ranges

The stringent specifications for calcium carbonate fillers and coatings required by the paper manufacturing industry are reflected in the prices for the products. Table 3-11 lists the prices of various calcium carbonate grades which are used by the paper industry as fillers and/or coatings.

Grade	Cost $Can/tonne (f.o.b. plant)
dry 0.5-4 microns, bags and bulk	175-240
slurry, 2-4 microns	180-200
slurry, 1 micron	325
PCC, 0.5 microns	300-310
PCC, 0.05-0.5 micron	775

Table 3-11: Prices of calcium carbonate filler grades by the paper industry (Chemical Marketing Reporter, 1988).

3.3.5.4 Consumption Levels

Paper represents the largest consuming industry, in value, of mineral fillers and coatings in North America. Since the early 1970's through to 1985 the consumption of calcium carbonate in paper manufacturing steadily increased from essentially zero to approximately 7 percent of total North American filler consumption. This represents approximately 236,000 tonnes of calcium carbonate with 29% (67,000 tonnes) used as filler and the balance for coating.

In the Canadian sector of the study area, consumption of calcium carbonate by the paper industry, although not accurately known, is not large (Table 3-12). The number of plants in each province is given in the table (See also Figure 1-2).

	Nfld.	N.S.	P.E.I.	N.B.	Que.	Ont.
Year	'83	'83	'83	'87	'83	'83
No. of Plants	2	3	0	7	25	27
Tonnes Utilized	0	0	0	150	0	w

w - withheld

Sources: 1983 figures - Prud'homme and Francis (1987)
1987 figure - Davis (1987)

Table 3-12: Calcium carbonate filler and coating consumption by the paper industry in the Canadian sector of the study area.

As is the case of plastics and paint, available statistics detailing the consumption of calcium carbonate fillers by the paper industry in the United States do not permit the breakdown of national consumption figures as readily as do the Canadian statistics. The size of the potential U.S. market is quantified (Table 3-13) by quoting the number of paper mills operating in the study area (Figure 1-2), production capacities and the value of their shipments of paper and allied products.

The study area includes 32.8% of the U.S. paper manufacturing industry, in terms of the number of mills. These mills manufacture 39.4% of the total tonnage of paper produced in the U.S. which accounts for 23.1% of the total value of paper shipments in the country. Within the study area, the state of Maine far outstrips all other states in terms of total tonnage but lags substantially behind Pennsylvania and New York in terms of value of shipments. This implies that, the states of Pennsylvania and New York produce a higher proportion of high value papers than Maine.

	# of mills	% of national total	production (tonnes)	% of national total	value of shipments* ($x10^6$)	% of national total
Connecticut	8	1.4	681	1.0	1,159.9	1.2
Delaware	5	0.9	147	0.2	n/a	-
Maine	18	3.2	9,678	13.9	3,143.6	3.4
Massachusetts	35	6.2	2,291	3.3	2,569.3	2.8
New Hampshire	16	2.9	1,337	1.9	901.1	1.0
New Jersey	17	3.0	2,519	3.6	3,020.4	3.2
New York	47	8.4	4,864	7.0	4,298.7	4.6
Pennsylvania	31	5.5	5,373	7.7	5,971.3	6.4
Rhode Island	0	0	0	0	169.6	0.2
Vermont	7	1.3	513	0.7	384.1	0.4
U.S. Sector of Study Area, Totals	184	32.8	27,403	39.4	21,618.0	23.1
National Totals	561	100.0	69,495	100.0	93,414.4	100.0

* includes "allied products"
$ - U.S. dollars

source: American Papermaker, 1988 Mill Directory
Lockwood's Directory of the Paper and Allied Trades, 1979

Table 3-13: Number of mills, production capacities and value of shipments of paper mills in the U.S. sector of the study area.

Specialty, filled and particularly coated papers are among several paper products which command relatively high prices in comparison to newsprint, for example. It is expected that Pennsylvania and New York paper mills would therefore produce a higher proportion of calcium carbonate filled and coated papers.

3.3.6 Putty, Caulks and Sealants

3.3.6.1 Applications

Putty, caulks and sealants are a group of related products with wide ranging industrial and domestic applications. Ground calcium carbonate is a widely used filler, providing bulk and reinforcing properties to these products. Its excellent availability, whiteness, low oil absorption and low cost make it the filler of choice for these applications. Low oil absorption permits high loading levels while maintaining good flow and viscosities in the finished product. High oil absorption by the filler particles yields a "dry" product having poor flow characteristics. Since most of these products are applied from gun type cartridges good flow properties are important. Filler loading is usually 40 to 50 percent by weight of the finished product but can be as high as 90 percent in putty in which calcium carbonate is most commonly used.

3.3.6.2 Specifications

Calcium carbonate fillers used in putty, caulks, and sealants cover a wide range of dry ground, air classified products. Average particle sizes range from 2 to 3 microns through to as large as 20 percent retained on a 200 mesh sieve (75 microns). Sealants and caulking compounds

typically use the finer grades while coarser grades are used for putty. A number of grades of filler material are often mixed to achieve the desired properties in caulking compounds.

For most applications a good white colour is required. In some products, however, lower quality off-white calcium carbonate can be used.

3.3.6.3 Price Ranges

Prices for calcium carbonate fillers used in putty, caulks and sealants in northeastern North America range from $Can 70 to $Can 240 per tonne f.o.b. the plant (Chemical Reporter, 1988).

3.3.6.4 Consumption Levels

Putty, caulks and sealants represent a large diversified group of products with a wide range of industrial applications. The estimated annual volume of putty, caulks and sealants produced in North America exceeds 225,000 tonnes, estimated to be worth approximately $1 billion (Canadian). Industrial and construction uses consume two-thirds of total production. Consumer purchases account for the remainder.

Production of putty, caulks and sealants, as is the case for drywall jointing compounds is concentrated in the highly populated areas of the northeastern U.S., the U.S. midwest and west. In Canada, production is concentrated in the major industrial areas of Ontario, Quebec and the west. The population distribution figures presented in Section 3.3.2 (joint compounds) apply similarly to putty, caulks and

sealants. This suggests that 26% of the North American consumption of calcium carbonate used in these products is consumed within the study area. This equates to approximately 29,000 tonnes of calcium carbonate.

3.3.7 Rubber

3.3.7.1 Applications

Calcium carbonate fillers are used in soft rubber goods such as rubber floor covering, auto mats and other flexible rubber products. The filler is added to reduce product cost and provide a neutral base for colouring pigments. Calcium carbonate has no reinforcing properties in rubber but can be used at high loading levels without significantly affecting the softness or resilience of the product (Section 2.3.3.1 provides a general background discussion on the use of fillers in rubber).

Calcium carbonate fillers are commonly used in wire and cable coatings, automotive weather stripping and in some footwear applications.

Filler loading levels in low performance rubber products may be as high as 50 percent by weight. Lower filler levels are used in higher performance products. Specific fillers may be added to the formulation to provide reinforcing properties.

3.3.7.2 Specifications

The most important physical properties required of calcium carbonate fillers used in rubber products relate to particle size distribution, whiteness and dispersion

properties. Average particle sizes of calcium carbonate products used in low performance rubber products range between 7 and 18 microns. In wire and cable coatings, calcium carbonate in conjunction with kaolin is used as a filler. Fine and ultrafine grades, both natural and stearate coated, the latter similar to surface treated grades used in plastics, are used.

3.3.7.3 Price Range

Prices commanded in northeastern North America by the coarser grades of calcium carbonate fillers used in rubber ranged from $Can 70 and $Can 240 per tonne f.o.b the plant. Stearate coated fine grades sold for $Can 240 per tonne f.o.b. the plant (Chemical Reporter, 1988).

3.3.7.4 Consumption Levels

In the Canadian sector of the study area, there is little information on consumption of calcium carbonate by the rubber industry (Table 3-14). The number of plants in each province in given in the table (See also Figure 1-5).

As is the case for plastics, paint and paper, available statistics detailing the consumption of calcium carbonate fillers by the rubber industry in the United States do not permit the generation of accurate consumption figures. The U.S. figures provide data (Table 3-15) relevant to the location by state (Figure 1-5) and the size of the potential market for calcium carbonate fillers in the rubber industry. The size of the potential market is quantified by quoting the number of firms manufacturing products which may contain calcium carbonate fillers and the value of shipments made by those firms. The statistics, due to their method of

compilation, overlap slightly with those quoted for the plastic industry with the result that the figures quoted in Table 3-15 are inflated somewhat from pure rubber industry figures.

	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.
Year	'85	'85	'85	'85	'85	'85
Tonnes Utilized:*						
-domestic prod.	0	0	0	0	w	w
-imports	undeter.	0	undeter.	12	936	2,800
No. of plants	0	0	4	0	36	79

*Partially used by the rubber industry, proportion used is unknown.

w - withheld

Sources: Utilization - Prud'homme and Francis (1987)
No. of plants - Statistics Canada (1983)

Table 3-14: Calcium carbonate filler consumption by the rubber industry in the Canadian sector of the study area.

The study area includes 23.4% of the U.S. rubber industry, in terms of number of firms in production. These firms ship approximately 8% of the total value of rubber products produced in the U.S. This wide variation is due in large part to the fact that there are relatively few firms (7.3% of total number of tire and tube manufacturers in the country) producing tires and tubes in the study area. These two products account for approximately 50% of the value of all shipments of rubber products in the U.S. and tend to be manufactured by relatively few firms (9.3% of total number of rubber fabricators in the country).

State/Commodity	No. of Firms	Percent of National Total	Value of Shipments ($x10^6$)	Percent of National Total
Connecticut				
tires and tubes SIC 3011	--	--	--	--
rubber and plastic footwear SIC 3021	--	--	--	--
rubber and plastic hose and belting SIC 3041	4	2.5	W	W
fabricated rubber products SIC 3069	37	2.7	137.7	2.2
State Totals	41	2.3	>137.7	>0.8
Delaware				
tires and tubes SIC 3011	--	--	--	--
rubber and plastic footwear SIC 3021	--	--	--	--
rubber and plastic hose and belting SIC 3041	--	--	--	--
fabricated rubber products SIC 3069	4	0.3	W	W
State Totals	4	0.2	W	W
Maine				
tires and tubes SIC 3011	--	--	--	--
rubber and plastic footwear SIC 3021	5	7.7	W	W
rubber and plastic hose and belting SIC 3041	--	--	--	--
fabricated rubber products SIC 3069	9	0.7	11.5	0.2
State Totals	14	0.8	>11.5	0.1
Massachusetts				
tires and tubes SIC 3011	--	--	--	--
rubber and plastic footwear SIC 3021	4	6.2	W	W
rubber and plastic hose and belting SIC 3041	4	2.5	W	W
fabricated rubber products SIC 3069	52	3.8	379.9	6.0
State Totals	60	3.4	>379.9	2.1

Table 3-15: Number of manufacturers and value of shipments of rubber and plastic in the U.S. sector of the study area.

State/Commodity	No. of Firms	Percent of National Total	Value of Shipments ($x10^6$)	Percent of National Total
New Hampshire				
tires and tubes SIC 3011	--	--	--	--
rubber and plastic footwear SIC 3021	4	6.2	w	w
rubber and plastic hose and belting SIC 3041	--	--	--	--
fabricated rubber products SIC 3069	15	1.1	w	w
State Totals	19	1.1	w	w
New Jersey				
tires and tubes SIC 3011	--	--	--	--
rubber and plastic footwear SIC 3021	4	6.2	w	w
rubber and plastic hose and belting SIC 3041	13	8.0	59.1	3.0
fabricated rubber products SIC 3069	74	5.4	249.3	3.9
State Totals	91	5.1	>308.4	1.7
New York				
tires and tubes SIC 3011	4	2.4	w	w
rubber and plastic footwear SIC 3021	3	4.6	w	w
rubber and plastic hose and belting SIC 3041	5	3.1	w	w
fabricated rubber products SIC 3069	74	5.4	w	w
State Totals	86	4.9	w	w
Pennsylvania				
tires and tubes SIC 3011	8	4.9	165.6	1.8
rubber and plastic footwear SIC 3021	8	12.3	76.3	10.8
rubber and plastic hose and belting SIC 3041	6	3.7	31.1	1.6
fabricated rubber products SIC 3069	55	4.0	304.2	4.8
State Totals	77	4.4	577.2	3.1

Table 3-15: Number of manufacturers and value of shipments of rubber and plastic in the U.S. sector of the study area. (continued)

State/Commodity	No. of Firms	Percent of National Total	Value of Shipments ($x10^6$)	Percent of National Total
Rhode Island				
tires and tubes SIC 3011	--	--	--	--
rubber and plastic footwear SIC 3021	--	--	--	--
rubber and plastic hose and belting SIC 3041	--	--	--	--
fabricated rubber products SIC 3069	20	1.5	w	w
State Totals	20	1.1	w	w
Vermont				
tires and tubes SIC 3011	--	--	--	--
rubber and plastic footwear SIC 3021	--	--	--	--
rubber and plastic hose and belting SIC 3041	--	--	--	--
fabricated rubber products SIC 3069	2	0.1	w	w
State Totals	2	0.1	w	w
U.S. Sector of Study Area, Totals				
tires and tubes SIC 3011	12	7.3	>165.6	>1.8
rubber and plastic footwear SIC 3021	28	43.2	>76.3	>10.8
rubber and plastic hose and belting SIC 3041	32	19.8	>90.2	>4.6
fabricated rubber products SIC 3069	342	25.0	>1,082.6	>17.1
State Totals	414	23.4	>1,414.7	>7.7
National Totals				
tires and tubes SIC 3011	164	9.3	9,340.1	50.8
rubber and plastic footwear SIC 3021	65	3.7	706.2	3.8
rubber and plastic hose and belting SIC 3041	163	9.2	1,963.6	10.7
fabricated rubber products SIC 3069	1,380	77.9	6,365.7	34.6
State Totals	1,772	100.1	18,375.6	99.9

SIC - Standard Industrial Classification
$ - U.S. Dollars
w - withheld

Source: 1982 Census of Manufacturers, U.S. Department of Commerce.

Table 3-15: Number of manufacturers and value of shipments of rubber and plastic in the U.S. sector of the study area. (continued)

3.4 Competitive Materials

Calcium carbonate fillers compete with several other fillers in many of its applications. The competition may be for either technical or economic reasons. Calcium carbonate is the filler of choice in such applications as carpet backing, polyvinyl chloride products, particularly vinyl flooring and in paint.

Asbestos is used as a reinforcing filler in plastics requiring high mechanical strength. Although formally common in vinyl flooring, this application has been much reduced in recent years. Asbestos is also used where heat resistance is important. In putty, caulks and sealants, asbestos provides thixotropy to the products so they will not sag, particularly on vertical surfaces.

Barite and precipitated barium sulphate, known as blanc fixe are gaining popularity in anti-rust primer paints. Their high impermeability and durability make them effective pigment extenders in these applications.

Barite and blanc fixe are used in small tonnages as filler in specialty papers. Blanc fixe is used in the manufacture of photographic papers. High whiteness, good rheological properties and satin finish when used as a coating agent results in their use for high quality papers such as heavy printing paper and playing cards.

Barite is also used as a filler in putty, caulks and sealants.

Bentonite is used as a filler in putty, caulks and sealants.

Carbon black is the most commonly used reinforcing filler in elastomer products.

Diatomite is used by the paper industry as a filler and pitch controller. It possesses enhanced dispersal characteristics which, when used in conjunction with titanium dioxide, improve its dispersal yielding increased capacity in the finished paper.

Gypsum has entered the plastics filler market on the strength of its low cost and suitability for both thermoplastics and thermosets. It appears to be well suited to halogenated polyester resin systems because, unlike calcium carbonate, it does not react with halogens.

The paper industry makes limited use of calcium sulphate (gypsum and anhydrite) as a filler. Use of this compound in papers however is limited by its natural solubility.

Kaolin is used in plastics requiring smooth attractive surfaces and resistance to chemicals. In polyvinyl chloride, kaolin is a reinforcing agent and improves durability and in glass reinforced polyesters it reduces flow problems in large items. Surface treated kaolin is gaining market strength due to improved dispersion properties much like calcium carbonate and talc.

Kaolin is the third major filler pigment used in paint, primarily due to its high covering characteristics, flow properties and cost. Calcined grades are used with increasing regularity due to their abrasion resistance and suitability as an extender for titanium dioxide, particularly in latex paints. Kaolin can be chemically

surface modified to be either hydrophylic or hydrophobic.

Kaolin is the primary filler used in the paper industry, performing both filler and coating functions. While providing smoothness, gloss, opacity, printability and ease of application due to low viscosity, the brightness and whiteness can be lower than desired. Improved beneficiation technologies, specifically high-intensity magnetic separation, however, have helped in removing impurities thus maximizing whiteness and brightness. Chemical inertness and insolubility are two key factors of kaolin's widespread acceptance in paper manufacturing.

Kaolin is used as a filler in putty, caulks and sealants.

Kaolin is the primary filler used in the manufacture of rubber products. It is used in both natural and synthetic rubber to lower cost and improve strength, abrasion resistance and rigidity.

Silica, particularly amorphous silica, is gaining popularity in anti-rust primers. Its high impermeability and durability make it an effective pigment extender. It is also used as a filler in putty, caulks and sealants.

Fumed silica is widely used as a reinforcing filler in silicone rubber but its use in organic elastomers has been limited due to its low bulk density.

Precipitated silica is utilized as a reinforcing filler in rubber but has never been as popular as carbon black.

Talc is a functional filler in plastics where it is used to improve chemical and heat resistance, impact strength, dimensional stability, stiffness, hardness, thermal conductivity and electrical insulation properties. It is used as a reinforcing extender in many thermoplastics in order to reduce creep in molded parts and increase heat deflection temperatures. Platey forms of talc are useful in that they facilitate extrusion and moulding.

Talc is the second most widely used filler pigment in paint. Talc's colour, chemical inertness, viscosity, ability to reinforce paint films and tendency to prevent settling of solids in the container are all positive features. Its softness and low abrasion and fineness are important to gloss control. Talc, being hydrophobic, is not compatible in water based paints.

Talc, while more commonly used as a filler in papers in Europe, ranks number four, after calcium carbonate in North America in this application. The provision of high reflectance and freedom from chemical additives, impurities and abrasives are key to talcs acceptance by the paper industry. Talc is also widely used as a pitch control agent through its selective absorption and dispersal, thus preventing paper spotting.

Talc is also used as filler in putty, caulks and sealants.

Titanium dioxide is the primary filler-pigment in vinyl siding. In this application it provides whiteness, opacity and ultra-violet light protection.

Titanium dioxide is the second most common filler used in paper manufacturing in North America. Eighty percent of the titanium dioxide used in paper is applied as a filler, as opposed to a coating. Titanium dioxide provides a high refractive index, excellent whiteness and remains opaque when in contact with oil (i.e. printing inks). The inertness of titanium dioxide to paper manufacturing chemicals and printing inks gives it broad application.

Wollastonite is used as a filler in the manufacture of vinyl flooring.

3.5 Trends and Market Potential

Research and practical application of calcium carbonate fillers in plastics has indicated that advantages can be gained from fillers treated with surface coatings, coupling agents, fine particle sizes and fillers with modified particle size distributions. Current research is aimed at achieving higher loading levels, finer grades, partial replacements of titanium dioxide and possible application of hybrid filler systems, such as combinations of calcium carbonate with aluminum tri-hydrate. Surface coatings enable higher loading levels, reduced melt viscosity, lower power requirements, improved rheological properties and better impact and aging properties. Coupling agents improve bonding between the resin and the filler but are not used as widely with calcium carbonates as with silicate minerals. This is primarily due to the lack of an appropriate coupling agent for calcium carbonate but research is ongoing.

The development of gypsum as a low cost filler for plastics together with its compatibility with halogenated polyester suggests that gypsum could displace calcium

carbonate in certain markets. Depending upon actual cost, gypsum could capture a portion of the low value non-functional plastics filler market now occupied by calcium carbonate.

The next generation of vinyl sidings for building construction may be a capped product with a weatherable outer surface over an inner core. The weatherable outer surface will continuously cleanse itself to retain its appearance. This form of siding has the potential for utilizing increased quantities of calcium carbonate fillers.

Calcium carbonate's hydrophylic properties and the increased acceptance of water based paints has enhanced its position as a paint pigment extender. Similarly, the development of calcium carbonate slurries and of ultrafine products in both dry and slurried form has had a positive impact with paint manufacturers. Slurries have reduced product handling costs for the manufacturers and yielded a superior product. Ultrafine products, being very efficient pigment extenders and having inherent dry hide characteristics, minimize the use of high cost primary pigment.

The availability and price of titanium dioxide, the leading pigment in paint, will in a large part determine the future markets of TiO_2 extenders and substitutes, such as calcium carbonate.

Increased utilization of calcium carbonate fillers in paper manufacturing depends, in large part, on the rate of conversion of paper mills from acid to alkaline or neutral sizing. The accelerated rate of conversions seen through the late 1970's, however, were adversely affected by the

poor economy of the early 1980's. In addition, managers of converted mills were faced with expensive learning curves associated with their newly converted manufacturing processes and knowledge of these costs is widespread. The impetus for conversion in the coming years will likely come from steadily increasing fiber costs.

3.6 Capital Cost of a Precipitated Calcium Carbonate (PCC) Facility

Production of non-dedicated precipitated calcium carbonate (see section 3.2.2.2.2) is currently conducted by Pfizer Inc. at Adams Mass. (9,000-18,000 tonnes per year) and Mississippi Lime Co. at Ste. Genevieve, Mo. (145,000 tonnes per year). Dedicated production of precipitated calcium carbonate is also carried out at several locations using "portable" facilities (see section 3.3.5).

Consumption trends and market demands reflect a continuing progression to finer particle size requirements. PCC production is a method of meeting this market demand, and an analysis of the capital cost of such a facility has been included as part of this study. The cost information included herein may be used as a base line for comparing various methods of obtaining the raw materials and operating a plant.

3.6.1 Determination of Facility Size

The level of consumption of PCC within the study area is difficult to determine with the available information. In view of this, estimates of consumption have been developed by two methods in order to select a size level for the facility for the purposes of the calculations.

In the first method, an existing level of production of 158,500 tonnes per year (154,000 to 163,000 tonnes) was used based on the reported output of the two North American producers. As discussed in section 3.3.2.1, the population of the study area is approximately 26% of the population of North America. Using these figures a consumption of 41,200 tonnes (158,500 X 26%) can be estimated for the study area.

The second calculation method was based on consumption data (see earlier sections of this chapter for details):

a) plastic industry

Canada[a]	3,800 tonnes*
U.S. (% of value of US production originating from study area)	
25.7%[b] x (385,000[c]-3,800)	97,968*
	101,768

Sources: a - Table 3-7
b - Table 3-8
c - Table 3-3

b) paint industry

Canada[d]	13,700*
U.S. (% of value of U.S. production originating from study area)	
17.8%[e] x (222,000[f]-13,700)	37,077*
	50,777

Sources: d - Table 3-9
e - Table 3-10
f - Table 3-3

Sub Total 152,545

Based on:

(i) total North American PCC production - 158,500** tonnes and
(ii) total North American GCC utilization - 1,885,000 (Table 3-3)

a ratio of PCC to GCC can be developed:

PCC/GCC = 158,000/1,885,000 = 8.4%

Based on GCC utilization, the utilization of PCC in the paint and plastic industry in the study area is:

152,545 x 8.4% = 12,800 tonnes

Sub Total	12,800

* ground calcium carbonate (GCC) production

** excluding dedicated PCC

c) paper industry

Canada[g]	neglible
U.S. (% of value of U.S. production originating from study area) 23.1%[h] X 136,000[i] =	31,416 tonnes
Total	44,216 tonnes

Sources: g - Table 3-12
h - Table 3-13
i - Table 3-3

The calculations based on population density and on consumption data yield estimates of the same order of magnitude (41,210 tonnes and 44,216 tonnes). An estimated consumption level of 40,000 tonnes per year has been assumed for the purposes of this study. However, it should be recognized that a new producer would have to overcome established market links between consumers and existing producers. Transportation aspects would also require evaluation. For the purposes of calculation it has been assumed that 30% of the market could be captured. Thus a market level of 12,000 tonnes per year (40,000 tonnes x 30%) has been assumed. This selected level of production compares well with reported production of 9,000 to 18,000 tonne per year at Pfizer Inc's Adams, Mass. facility. Based on a price of $Can 300 per tonne (Table 3-11), this size

would have a production capability valued at $3.6 million.

3.6.2 Selection of Production Method

PCC can be produced by the three methods described in Section 3.2.2.2.2. The carbonation method is one in which carbon dioxide gas reacts with calcium hydroxide slurry called milk-of-lime to produce calcium carbonate slurry. In the lime soda method sodium carbonate and milk-of-lime react to produce calcium carbonate in a sodium hydroxide (caustic soda) solution. After extracting and neutralizing the PCC, the caustic soda is a by-product. The Solvay method is a process where the raw materials react to yield PCC and the by-products of ammonia gas and a sodium chloride solution.

Comparison of the estimated cost of the major raw materials and revenue from by-products for various methods of production of 12,000 tonnes per year of PCC are displayed in Table 3-16. The estimated revenue obtainable from the by-products of PCC production as shown in the table are low because consideration was not given to further refinement or treatment of the by-products. Since the additional processing of by-products would greatly increase the capital cost of a production facility, cost analyses including such processing would be inappropriate for determining the most attractive method of producing PCC.

In Table 3-16 production methods 1 and 2 are similar, differing in that in Method 1, the raw material is quicklime hydrated in the process, and in Method 2, the raw material is hydrated lime from the lime supplier. The difference in the cost of purchasing quicklime or hydrated lime is shown in the table as favoring quicklime. Capital and operating

	Production Method			
	1	2	3	4
Raw Material Cost	1,964,000	2,299,000	3,877,000	9,637,000
Revenue from By-Products	0	0	480,000	248,000
Net Material Cost	1,964,000	2,299,000	3,397,000	9,389,000

Notes:
Method 1: Carbonation process using quicklime.
Method 2: Carbonation process using hydrated lime.
Method 3: Lime soda process.
Method 4: Solvay process.

Table 3-16 Raw material costs for producing PCC.

cost estimates support the advantage of quicklime as the less costly material. This may be inferred from information referenced on operating costs later in this section.

Order of magnitude cost estimates indicated that the capital cost of production plants for the various methods defined in Table 3-16 do not vary. A review of the raw material costs would thus lead to the selection of the carbonation method using quicklime for the production of PCC.

A PCC production facility using the carbonation method may obtain the carbon dioxide as a pure product delivered in bulk from gas suppliers or from the exhaust of lime calcining kilns. Since kiln exhaust is approximately 24 percent carbon dioxide, the cleaning and handling of the larger volume of kiln exhaust gas for a given quantity of carbon dioxide favors the use of the pure carbon dioxide. For an independent PCC producer, the difficulties associated with obtaining a suitable supply of kiln exhaust gas again favor pure carbon dioxide. A production facility associated with a lime calcining kiln may have the economic attractiveness to warrant the additional capital and

production costs to utilize the kiln exhaust. Since such an arrangement would preclude a totally independent producer, it is not considered in the context of this study and the cost evaluations.

Because the materials dry quicklime and carbon dioxide gas used in the carbonation method are readily available, easily handled and relatively safe, this is the favored production method. Another important advantage would be the minimum amount and non-polluting effect of the waste and by-products. Grit removed during the processing would contain mostly silica and carbonates introduced in the process as contaminants in the quicklime. The other production methods may yield large amounts of materials such as salts, gases, and caustic solutions that must be appropriately disposed of or sold as by-products. Comparison of the materials required to be handled in the production facility appears to favor the carbonation method of producing PCC in the study area.

Since the primary objective of the envisaged production facility is to produce a high quality PCC, the added process step of slaking quicklime in the carbonation method increases the control over the quality of the product. The remaining discussion refers to such a proposed facility.

3.6.3 Production Plant

The proposed PCC production process using the carbonation method is depicted schematically in Figure 3-3. The figure is simplified to merely display the basic technology involved. The quicklime storage bin and the PCC storage tank are sized for two days of production, with approximately 15 percent extra capacity. These sizes are

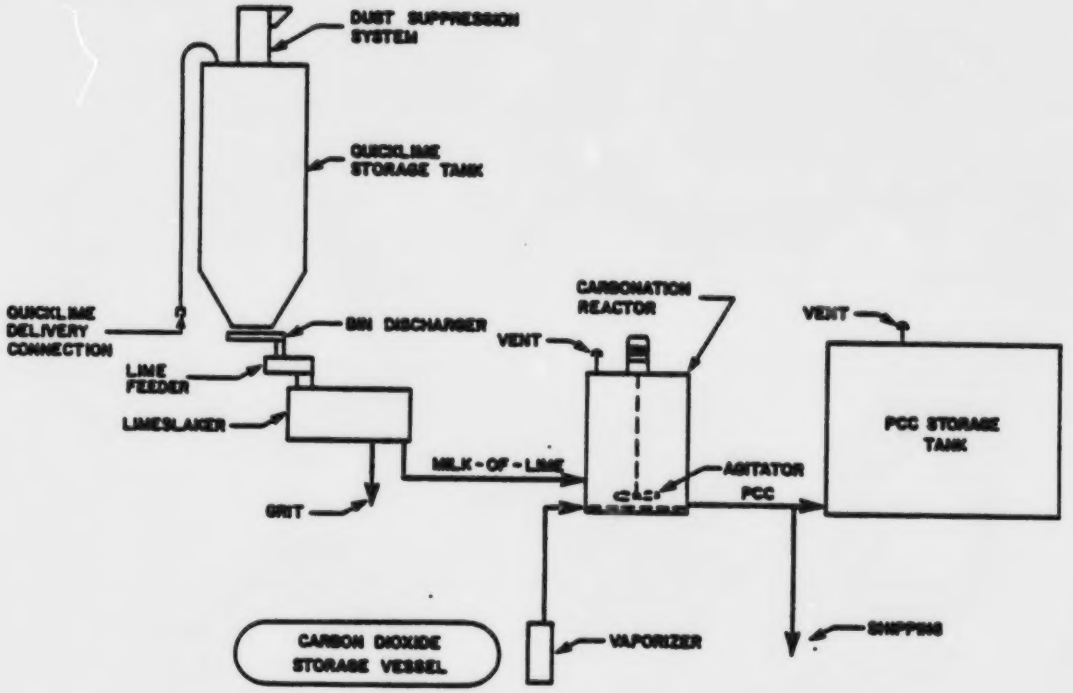

Figure 3-3: Simplified flowsheet for production of precipitated calcium carbonate.

considered the minimum to avoid disruptions in production due to an interruption in the delivery of quicklime or the shipping of PCC. The proposed facility has been visualized to be located within a moderate distance from a source of quicklime and within the Province of New Brunswick.

3.6.4 Cost Analysis

A plant for the production of 12,000 tonnes of PCC per year by the carbonation method using quicklime would cost in the order of $560,000 if production were to be 24 hours per day for five days per week. Should production occur during an eight-hour period each week day, the cost of the facility would be approximately $608,000. These capital costs include all design, construction, and commissioning for the fixed buildings, structures, site facilities, material handling facilities, processing facilities, and all utility, operation and maintenance facilities.

Excluded from the plant costs are the cost of land, mobile equipment such as fork lifts and vehicles, rail and highway facilities, and any costs associated with the facility but off-site of the immediate facility, and the cost of activities not directly required for the design, construction and commissioning of the facility.

The annual cost of operating a PCC facility will differ for the 24 hours per day and 8 hours per day production periods. These costs are presented in Appendix 3-1. The annual operating cost is greater for the 24 hours per day operation which was previously shown to be the lesser capital cost alternative. In order to determine the more cost effective alternative, the annual operating cost of each has been converted to a single value that represents

the worth in todays dollars of the annual costs occurring over the life of the facility. The analysis is displayed in Appendix 3-2. By the addition of each present worth to the respective present capital cost, the present total worth of each alternative is established. The production facility alternative with the lesser present total worth is the more cost effective. In all of the analyses, the 8 hours per day alternative has the lesser present total worth and is concluded to be the more cost effective.

The printouts in Appendix 3-2 are two series of sensitivity analyses, the first of which, designated as Tables 3-2A through 3-2F, vary the present-worth interest rate from 9 percent to 14 percent. The second series of printouts, designated as 3-2G through 3-2N, vary the plant operation period from 10 years to 45 years. Current financial indicators lead to the conclusion that the range of conditions exhibited in Appendix 3-2 are appropriate. Throughout, the advantage remains with the plant operating for 8 hours per day as more cost-effective primarily due to the lower labour costs by having a smaller labour force. Constructing a plant to operate eight hours per day provides the added benefit of more easily increasing production in the future, should the need arise.

Presented also in the tables of Appendix 3-2 is the unit production worth which is the present total worth per tonne of annual production. Based on the unit production worths, shown in the tables, the cost of producing each tonne of PCC in the facility operating at 8 hours per day ranges from $186.77 to $191.34. With a selling price in the order of $300 per tonne (Table 3-11) for technical grade (0.5 micron) material the production of PCC appears financially viable. Ultrafine and surface treated products

command higher prices. The $300 per tonne value (about $US 210/ton) represents a list price. Discounting of prices is reportedly common.

3.6.5 Limitations and Considerations

Coating grades of PCC generally exhibit low abrasiveness, by exclusion of grit, and true white color, by having in excess of 97.5 percent of calcium carbonate. Since PCC whiteness is reduced by magnesium carbonate, the quicklime must have a proportionately high calcium oxide composition. What is referred to as "high calcium quicklime", contains some value less than five percent magnesium oxide. In order to produce a high value PCC, the purity of the quicklime must be closely defined.

The particle size of coating grades of PCC range from 30 microns down to less than 0.1 micron. The most expensive and least available product is in the finer size range from five microns and less. Particle size is a function of processing equipment and the control parameters of the various stages in the production process. Skilled operators and proper maintenance are a necessity in a high quality PCC facility.

The technology involved in producing high quality PCC is specialized and presently restricted to those firms having achieved success through extensive research and development. Some firms presently construct and operate production facilities to serve a single user of PCC or a limited market. As discussed in other sections of this report, a few firms produce PCC for the general market. Development of a production facility independent of the current producers would require a manufacturer with the

ability and resources to institute the processing and operating refinements necessary to produce the PCC quality demanded by the market.

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APPENDIX 3-1

COST OF OPERATING A PCC FACILITY

OPERATOR WAGE, $/h	20
PRODUCTION DAYS PER YEAR d/a	250
WAGE PAY DAYS PER YEAR, d/a	260

OPERATION ITEM		24 h/d					8 h/d				
	RATE	unit	$/unit	$/d	$/a	$/te prod	unit	$/unit	$/d	$/a	$/te prod
OPERATORS:											
Labour	mnh/d	64	20.00	1280	332800	27.73	32	20.00	640	166400	13.87
RAW MATERIALS:											
CaO	te/a	7674	110.00		844140	70.35	7674	110.00		844140	70.35
CO2	te/a	5541	202.17		1120224	93.35	5541	202.17		1120224	93.35
Additives	year				4000	0.33				4000	0.33
UTILITIES:											
Water	$/a				1820	0.15				2012	0.17
Electricity	$/a				19591	1.63				16064	1.34
MAINTENANCE SUPPLIES:											
	$/a				8032	0.67				5635	0.47
WASTE DISPOSAL:											
Complete	te/a	620	11.94		7400	0.62	620	11.94		7400	0.62
VEHICLES:											
Lease	$/m		560.00		6720	0.56		560.00		6720	0.56
CONTRACTS:											
Maint & Serv	$/a				2500	0.21				2300	0.19
INSURANCE:											
Property	$/a				2650	0.22				3050	0.25
PROPERTY TAX:											
Site	$/a				1400	0.12				1556	0.13
COST OF OPERATION	$/a				2351277	195.94				2179501	181.63

ABBREVIATIONS:

a	annum
d	day
m	month
mnh	manhours
te	tonnes
te prod	tonnes produced

Table 3-1A: Annual cost of operating a PCC facility producing 12,000 tonnes per year.

APPENDIX 3-2

PRESENT WORTH OF THE COST OF OPERATING A PCC FACILITY SENSITIVITY ANALYSIS

SENSITIVITY ANALYSIS: RUN 1
VARIABLE: "Present Worth Interest Rate"

PRESENT WORTH INTEREST RATE	9%
PLANT OPERATION PERIOD	10 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	15,089,690.75	1,257.47	608,000.00	13,987,291.18	1,165.61
PRESENT TOTAL WORTH $	15,649,690.75			14,595,291.18		
UNIT PRODUCTION WORTH $/te			1,304.14			1,216.27

Table 3-2A: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 2
VARIABLE: "Present Worth Interest Rate"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	10 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	14,447,579.13	1,203.96	608,000.00	13,392,089.97	1,116.01
PRESENT TOTAL WORTH $	15,007,579.13			14,000,089.97		
UNIT PRODUCTION WORTH $/te			1,250.63			1,166.67

Table 3-2B: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 3
VARIABLE: "Present Worth Interest Rate"

PRESENT WORTH INTEREST RATE	11%
PLANT OPERATION PERIOD	10 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	13,847,215.60	1,153.93	608,000.00	12,835,586.88	1,069.63
PRESENT TOTAL WORTH $	14,407,215.60			13,443,586.88		
UNIT PRODUCTION WORTH $/te			1,200.60			1,120.30

Table 3-2C: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 4
VARIABLE: "Present Worth Interest Rate"

PRESENT WORTH INTEREST RATE	12%
PLANT OPERATION PERIOD	10 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	13,285,239.28	1,107.10	608,000.00	12,314,666.57	1,026.22
PRESENT TOTAL WORTH $	13,845,239.28			12,922,666.57		
UNIT PRODUCTION WORTH $/te			1,153.77			1,076.89

Table 3-2D: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 5
VARIABLE: "Present Worth Interest Rate"

PRESENT WORTH INTEREST RATE	13%
PLANT OPERATION PERIOD	10 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	12,758,601.32	1,063.22	608,000.00	11,826,502.92	985.54
PRESENT TOTAL WORTH $	13,318,601.32			12,434,502.92		
UNIT PRODUCTION WORTH $/te			1,109.88			1,036.21

Table 3-2E: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 6
VARIABLE: "Present Worth Interest Rate"

PRESENT WORTH INTEREST RATE	14%
PLANT OPERATION PERIOD	10 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	12,264,532.59	1,022.04	608,000.00	11,368,529.11	947.38
PRESENT TOTAL WORTH $	12,824,532.59			11,976,529.11		
UNIT PRODUCTION WORTH $/te			1,068.71			998.04

Table 3-2F: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 1
VARIABLE: "Plant Operation Period"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	10 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	14,447,579.13	1,203.96	608,000.00	13,392,089.97	1,116.01
PRESENT TOTAL WORTH $	15,007,579.13			14,000,089.97		
UNIT PRODUCTION WORTH $/te			1,250.63			1,166.67

Table 3-2G: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 2
VARIABLE: "Plant Operation Period"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	15 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	17,883,999.58	1,490.33	608,000.00	16,577,457.66	1,381.45
PRESENT TOTAL WORTH $	18,443,999.58			17,185,457.66		
UNIT PRODUCTION WORTH $/te			1,537.00			1,432.12

Table 3-2H: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 3
VARIABLE: "Plant Operation Period"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	20 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	20,017,746.31	1,668.15	608,000.00	18,555,320.39	1,546.28
PRESENT TOTAL WORTH $	20,577,746.31			19,163,320.39		
UNIT PRODUCTION WORTH $/te			1,714.81			1,596.94

Table 3-2I: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 4
VARIABLE: "Plant Operation Period"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	25 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	21,342,635.15	1,778.55	608,000.00	19,783,417.52	1,648.62
PRESENT TOTAL WORTH $	21,902,635.15			20,391,417.52		
UNIT PRODUCTION WORTH $/te			1,825.22			1,699.28

Table 3-2J: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 5
VARIABLE: "Plant Operation Period"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	30 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	22,165,286.88	1,847.11	608,000.00	20,545,969.22	1,712.16
PRESENT TOTAL WORTH $	22,725,286.88			21,153,969.22		
UNIT PRODUCTION WORTH $/te			1,893.77			1,762.83

Table 3-2K: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 6
VARIABLE: "Plant Operation Period"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	35 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	22,676,088.89	1,889.67	608,000.00	21,019,453.84	1,751.62
PRESENT TOTAL WORTH $	23,236,088.89			21,627,453.84		
UNIT PRODUCTION WORTH $/te			1,936.34			1,802.29

Table 3-2L: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 7
VARIABLE: "Plant Operation Period"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	40 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	22,993,256.74	1,916.10	608,000.00	21,313,450.53	1,776.12
PRESENT TOTAL WORTH $	23,553,256.74			21,921,450.53		
UNIT PRODUCTION WORTH $/te			1,962.77			1,826.79

Table 3-2M: Present worth of the cost of operating a PCC facility.

SENSITIVITY ANALYSIS: RUN 8
VARIABLE: "Plant Operation Period"

PRESENT WORTH INTEREST RATE	10%
PLANT OPERATION PERIOD	45 years
ANNUAL PLANT PRODUCTION	12000 te/a

OPERATION	24 h/d			8 h/d		
COSTS	$	$/a	$/te	$	$/a	$/te
CAPITAL COST	560,000.00			608,000.00		
TOTAL COST OF OPERATION		2,351,276.97	195.94		2,179,500.97	181.63
PRESENT WORTH	560,000.00	23,190,193.03	1,932.52	608,000.00	21,495,999.34	1,791.33
PRESENT TOTAL WORTH $	23,750,193.03			22,103,999.34		
UNIT PRODUCTION WORTH $/te			1,979.18			1,842.00

Table 3-2N: Present worth of the cost of operating a PCC facility.

CHAPTER 4.0: KAOLIN

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4.0 KAOLIN

4.1 Introduction and Overview

Kaolin, or china clay as it is commonly called in Europe, is a clay consisting mainly of pure kaolinite ($Al_2O_3.2S.O_2.2H_2O$) or related clay minerals such as nacrite, dickite and halloysite. It has a naturally white or nearly white colour, or can be beneficiated to this colour. It will fire white or nearly white and is amenable to beneficiation to make it suitable for use as a filler. Kaolinite is a secondary mineral, formed of feldspathic minerals by chemical weathering or hypothermal alteration. Most kaolin occurrences formed during the Cretaceous Period of geological time when world climate was generally warmer and more humid than present.

There are two types of kaolin deposits, residual and sedimentary. Residual deposits are the result of chemical weathering of feldspathic rocks. The resulting kaolinite remains in place within a matrix of more resistant minerals such as quartz, mica and potassium feldspar. These deposits typically have an irregular shape and grade into partly decomposed rock and unweathered bedrock with depth. Sedimentary deposits may be formed by the transport of residual kaolinite by streams to a fresh water depositional basin (kaolinite is unstable under marine conditions). More commonly, sedimentary kaolin deposits are the result of kaolinization of a previously deposited feldspathic sand. Sedimentary deposits often consist of tabular lenses and discontinuous beds.

The United States produces approximately 40% of the world's supply of kaolin, primarily from sedimentary

deposits in Georgia and South Carolina. The United Kingdom is the world's largest exporter of kaolin and third after the Eastern bloc countries in total production. The Eastern bloc produces approximately 25% and the U.K. 16% of the world's supply. The balance of the world production (20%) originates from several countries. Canada does not currently produce kaolin.

The residual deposits in Cornwall (southwest U.K.) are second only to Georgia in world production of paper-coating grades. Production in both countries is from open pits: the Georgia deposits are worked by draglines whereas the Cornwall deposits are mined hydraulically using water jets. Brazil ranks third in world production of paper-coating grades of kaolin but also produces other grades of product.

Kaolin has several properties that are important in its use as a filler. It is chemically inert over a relatively wide pH range; is white in colour; has good covering power when used as a pigment or extender in coating and filling applications; is soft and non-abrasive; has low conductivity of heat and electricity; and is lower in cost than most competing materials. All kaolins, however, must be processed to some degree in order to prepare a suitable product. The process selection depends on the nature of the deposit and the intended applications of the product. Dry processing is usually restricted to sedimentary deposits containing a high percentage of kaolin and yields a product which meets less stringent specifications of particle size, particle size distribution and purity. Wet processing is more complex and is used for the more refined product required for paper coating and most paper fillers. Wet processing is generally necessary for production from residual deposits containing high percentages of abrasive

components. Wet processing can include such beneficiation techniques as fractionation to obtain the desired particle size distribution, bleaching for brightness, magnetic separation to improve purity, and delamination to achieve desired particle sizes. Calcining is used to improve brightness, whiteness, oil absorption and electrical resistivity. Kaolin surface treated with special organic chemicals will improve performance of air floated, water washed or calcined products.

The products produced by the kaolin industry can be broken down into four basic grades of clay used in filler applications. These grades are water washed, air-floated, delaminated and calcined. Each name denotes the type of processing the crude kaolin undergoes before reaching its end-use form. These are discussed in more detail in Section 4.2.2.2. Water washed kaolin is the most utilized grade, accounting for approximately 60% of the total estimated kaolin consumption and over 50% of the total value. Calcined kaolin usually demands the highest price of the four grades and is used as a filler and extender. Delaminated kaolin is used extensively as a coating for light weight coated paper. Air floated kaolin is the least refined and therefore the least expensive grade.

In general, filler grades are produced to a specified brightness and grit content. Table 4-1A lists common filler grades and brightness requirements.

Many grades of coating kaolin are available based on particle size, particle shape and brightness. Table 4-1B lists the coating grades, their required particle size and brightness.

In North America, the paper industry is the largest consumer of kaolin for use as both a filler and as a coating medium. The paint, plastics and rubber industries are significant, but lower volume, consumers. Adhesives, inks, and a variety of other uses represent a small portion of the North American market.

Grade	% Brightness
Regular air floated	79 - 81
Fine air floated	81 - 83
High brightness fine air floated	83 - 85
Regular water washed	81 - 83
Fine water washed	83 - 84
High brightness fine water washed	84 - 86
Delaminated filler	87 - 88
High brightness delaminated filler	89 - 91
Calcined extender filler	92 - 93

Table 4-1A: Kaolin filler grades and brightness (Murray, 1984)

Grade	Particles	% Brightness
Regular (water washed):		
No. 3	73% <2um	85.0 - 86.5
No. 2	80 - 82% <2um	85.5 - 87.0
No. 1	90 - 92% <2um	87.0 - 88.0
Fine No. 1	95% <2um	86.0 - 87.5
Delaminated:		
Regular	80% <2um	88.0 - 90.0
Fine	95% <2um	87.0 - 88.0
High Brightness (water washed):		
No. 2	80% <2um	89.0 - 91.0
No. 1	92% <2um	89.0 - 91.0
Fine No. 1	95% <2um	89.0 - 91.0
Special:		
Low glossing	50% <2um	87.5
Calcined extender	85 - 90% <2um	92.0 - 93.0
Rotogravure	45 - 50% <2um	>84.5

Table 4-1B: Kaolin coating grades, particles and brightness (Murray, 1984)

4.2 Production of Kaolin

4.2.1 Location and Capacity of Producers

Thirty-four producers of kaolin are listed (Table 4-2) for North America. All are located in the United States with the majority in Georgia (Figure 4-1). High quality paper fillers and coatings are almost exclusively produced in Georgia which monopolizes water washed and delaminated kaolin production. The balance of the producing states, Alabama, California, Florida, South Carolina, North Carolina and Texas, serve mainly ceramic, refractory and other filler uses. There is no production within the study area. Table 4-2 indicates that the North American annual production capacity is in excess of 7,000,000 tonnes. The United States Bureau of Mines (1986) estimates actual 1986 production to be 7,754,380 tonnes.

4.2.2 Mining, Processing and Beneficiating Technology

4.2.2.1 Mining

Conventional open pit mining methods are used to extract kaolin in the United States. Deposits in southern England are commonly mined using hydraulic methods such as high pressure water jets. The southern United States deposits are of sedimentary origin resulting from the weathering of granite and the alteration of feldspar to kaolinite. This material was transported by streams to the ocean, which at the time (50 to 90 million years ago) was

Company	Location	Capacity (000 tonnes)	Remarks
Albion Kaolin Co.	Hephzabah, GA	181	
American Cyanamid Co.	Andersonville, GA	n.a	Bauxite/kaolin operation for firebricks, alum, and bleaching agent for paper.
American Industrial Clay Co.	Sandersville, GA Wrens, GA	n.a	
Anglo American Clays	Sandersville, GA	317	A member of the ECC Group-mostly coating clays.
Babcox & Wilcox Co.	Hephzibah, GA	181	Mostly for refractories, but some for ceramics and glass fibre.
Buffalo China Clay Co.	Sandersville, GA	45	Subsidiary of American Industrial Clays and Champion Papers Inc.
Burgess Pigment	Sandersville, GA	n.a.	Mostly calcined and surface treated clays for paint, rubber and plastics.
Cyprus Industrial Minerals	Sandersville, GA	218	Mostly for putty, caulks, sealants and adhesives.
C-E Minerals	Andersonville, GA	544	A bauxitic/kaolonitic clay used mostly for refractories.
Didier-Taylor	Eufaula, Alabama	91	Bauxitic/kaolinitic clay for refractories.
Dixie Clay Co.	Bath, SC	136	Air-floated clays mainly for rubber and plastics. A subsidiary of R.T. Vanderbilt.
Texas Industrial Minerals	Kosse, Texas	n.a.	Calcined kaolin for paint. Subsidiary of Ottawa Silica Co.
Edgar Plastic Kaolin	Edgar, Florida	32	Owned by Pacific Tin Consolidated. Lump and pulverised kaolin for floor tiles, sanitary ware, and electrical porcelain.
Engelhard Minerals & Chemicals	Sandersville, GA Irwinton, GA) McIntyre, GA*) Gardner, GA	n.a. 1343 n.a.	Water washed clays, for paper, paint and adhesives.
Evans Clay Co.	Irwinton, GA	109	Clay used in rubber, paint, and insecticide industries.

Table 4-2: North American (US) kaolin producers (Page 1)

Company	Location	Capacity (000 tonnes)	Remarks
Eufaula Minerals	Eufaula, Alabama	272	A subsidiary of C-E Minerals. A kaolin/bauxite product for refractories.
Freeport Kaolin Co.	Sandersville, GA Gordon, GA	544	Approximately 58% to paper; the rest to rubber, paint, adhesives plastics.
Fountain Kaolin Co.	Irwinton, GA	n.a.	
General Refractories	Stevens Pottery, GA	n.a.	Clay for refractories.
Georgia Kaolin Co. American Ind. Clay Corp.	Dry Branch, GA) Sandersville, GA) Wrens, GA)	>1451	Both companies are part of Combustion Engineering; Georgia Kaolin operates the Dry Branch and Wrens plants, and AIC the Sandersville plant, both being served by a number of clay pits.
A.P. Green Refractories	Eufaula, Alabama	54	Bauxite/kaolin clay for refractories.
Harbison Walker Refract.	Eufaula, Alabama	272	Bauxite/kaolin clay for refractories.
Harris Mining	Spruce Pine, NC	14	Mica/kaolin/sand operation.
J.M. Huber Corp.	Wrens, GA) Huber, GA) Langley, SC) Graniteville, SC) Edisto, SC)	1179	The Georgia operations produce kaolin for paper, rubber, plastics, paint, and adhesives. At the South Carolina facilities air-floated and water washed products are processed for the rubber, fiberglass, conditioning, and agricultural markets.
Medusa Portland Cement Co.	Perry City, GA	n.a.	Material for additive to cement production.
M&M Clays Inc.	Irwinton, GA	73	Clays for the rubber industry.
National Kaolin Products	Aiken, SC	91	Part of the W.R. Grace Group. Sales mostly for rubber.
Nord Kaolin Co.	Jeffersonville, GA	268	Virtually all for paper.

Table 4-2: North American (US) kaolin producers (Page 2)

Company	Location	Capacity (000 tonnes)	Remarks
Southeastern Clay Co.	Aiken, SC	45	
Thiele Kaolin	Sandersville, GA	363	The bulk of production serves the paper industry (coating and filler).
	Wrens, GA	227	
Thomas Alabama Kaolin	Marion County, Alabama		Bauxite kaolin clay mainly for refractories.
Wilkinson Kaolin Associates Ltd.	Gordon, GA	109	

		> 7346	

n.a. not available

* undergoing significant expansion (Industrial Minerals, 1988)

Sources: Guillet and Kriens (1984), Watson (1984) and U.S. Bureau of Mines (1985)

Table 4-2 North American (US) kaolin producers (Page 3)

Figure 4-1 Distribution of kaolin production facilities in North America

much farther inland than its present position. The transportation by streams resulted in a natural size classification of the kaolin. Particle aggregation occurred due to the effect of ocean salinity and extensive beds of kaolin were deposited in lagoonal environments. The ocean subsequently regressed to its present position leaving deposits of high purity with low levels of "grit" and impurities.

Mining of these deposits is relatively straightforward. Once the deposit has been identified, a detailed drilling program is undertaken to determine quality. The overburden is removed using either self-propelled scrapers or draglines. Topsoil is stockpiled for subsequent use in reclamation.

A dragline is used to extract the kaolin and feed it into a mobile blunger. This mixing equipment was pioneered by Georgia Kaolin Co. and involves the dispersal of the clay in water to form a slurry (a dispersing agent is often used). Pugmills can be used to precondition the clay for the blungers.

The clay slurry is pumped to central degritting stations where coarse sand and mica are removed by gravity settling and/or wet cyclones, followed by screening. The product of this preliminary beneficiation is stored separately in tank farms until testing determines the blending necessary for feed to the main processing plant.

The slurry is pumped to the main processing plant through pipelines of 15 to 30 cm diameter, over distances of 10 to 32 km or more.

The deposits in the United Kingdom (Devon and Cornwall) are usually worked by hydraulic mining. These are residual deposits which may contain 10 to 40 percent kaolinite. The balance consists of unaltered, or partially altered, minerals and rock fragments. They are not as pure as the Georgia deposits, and a simple concentrating technique is essential to avoid handling excessive amounts of waste rock. This is accomplished by hydraulic mining, using high pressure water jets. The resulting slurry is collected in a pond and pumped into spiral classifiers to remove coarse material, then hydrocycloned to remove finer sand and mica.

4.2.2.2 Processing and Beneficiation

Kaolins are arbitrarily classified into "hard" and "soft" clays based on their physical properties rather than their physical form. Hard clays, when used in rubber, produce a high modulus, high tensile strength product with good abrasion resistance. Soft clays produce a lower modulus, lower tensile strength and abrasion resistance in rubber.

Commercial quality paper grade clays and soft rubber grade clays are produced from both residual and sedimentary deposits. Hard rubber grade clays are usually of sedimentary origin.

The selection of a process depends on the nature of the deposit and the product requirements. Ceramic and most rubber clays can be produced by dry processing of the dried crude kaolin after removal of coarse impurities. Some paper filling grades can also be produced by the dry process. The dry process consists of drying the clay, followed by pulverizing and air classification. This process is largely

restricted to sedimentary kaolin deposits containing a high percentage of kaolin such as those in Georgia.

Wet processing must be used to produce paper coating and most paper filler grades of kaolin. Wet processing is generally necessary for kaolin production from residual deposits containing high amounts of abrasive components.

Blending of product from several sources is a common component of the processing cycle. Selective mining and blending of slurries from several sources produces the feedstock required to achieve the desired quality of the end products.

4.2.2.2.1 Wet Processing

The initial processing of kaolin is essentially a process to remove abrasive minerals such as quartz, and other impurities such as mica and refractory minerals. This process is less complex in the case of secondary deposits which have undergone natural classification during transportation from their original sources. Most of the resistant minerals have been removed during transportation, leaving relatively small amounts of abrasive minerals. By contrast, the separation of kaolin from primary deposits is more difficult because of the generally high content of abrasive minerals, mica and other accessory minerals that have survived the alteration process.

In the initial separation process, the crude kaolin is slurried (blunged) in a drum with water, and a suitable dispersant is added to assist in the dispersion and deflocculation of the kaolin. The amount and type of dispersant is determined experimentally and is based on

achieving a minimum solution viscosity. The resulting slurry is discharged from the drum over a trommel screen which is an integral part of the washing drum. Coarse sand, roots, sticks and other contaminants, together with any undispersed clay lumps are retained on the screen and subsequently pumped or otherwise transferred to a spiral or rotary knife washer to which water is added. The coarse sand settles out and is conveyed by the action of the spiral or knives to the high side of the washer, while the kaolin slurry overflows from the low side of the washer. The coarse sand is pumped to the waste disposal system.

The kaolin slurry that passed through the trommel screen of the primary washer combines with the overflow from the secondary washer. At this point, the slurry consists of kaolin, fine sand and any remaining contaminants such as leaves, roots and other finely divided organic debris. It is pumped to static or vibrating screens equipped with water washers, to remove the remaining organic material. The underflow from the screen, free of these contaminants, is then pumped to hydrocyclones, primary centrifuges or settling tanks to remove fine sand (Figure 4-2).

In most cases, additional beneficiation is required to produce kaolin of commercial quality. This secondary processing can involve several methods depending on the characteristics of the slurry. Free silica or other abrasive material may still be present in unacceptable amounts. Fractionation using settling tanks, hydro-separators, hydrocyclones, or decanting centrifuges can be used to separate these abrasive components and also can produce grades of kaolin.

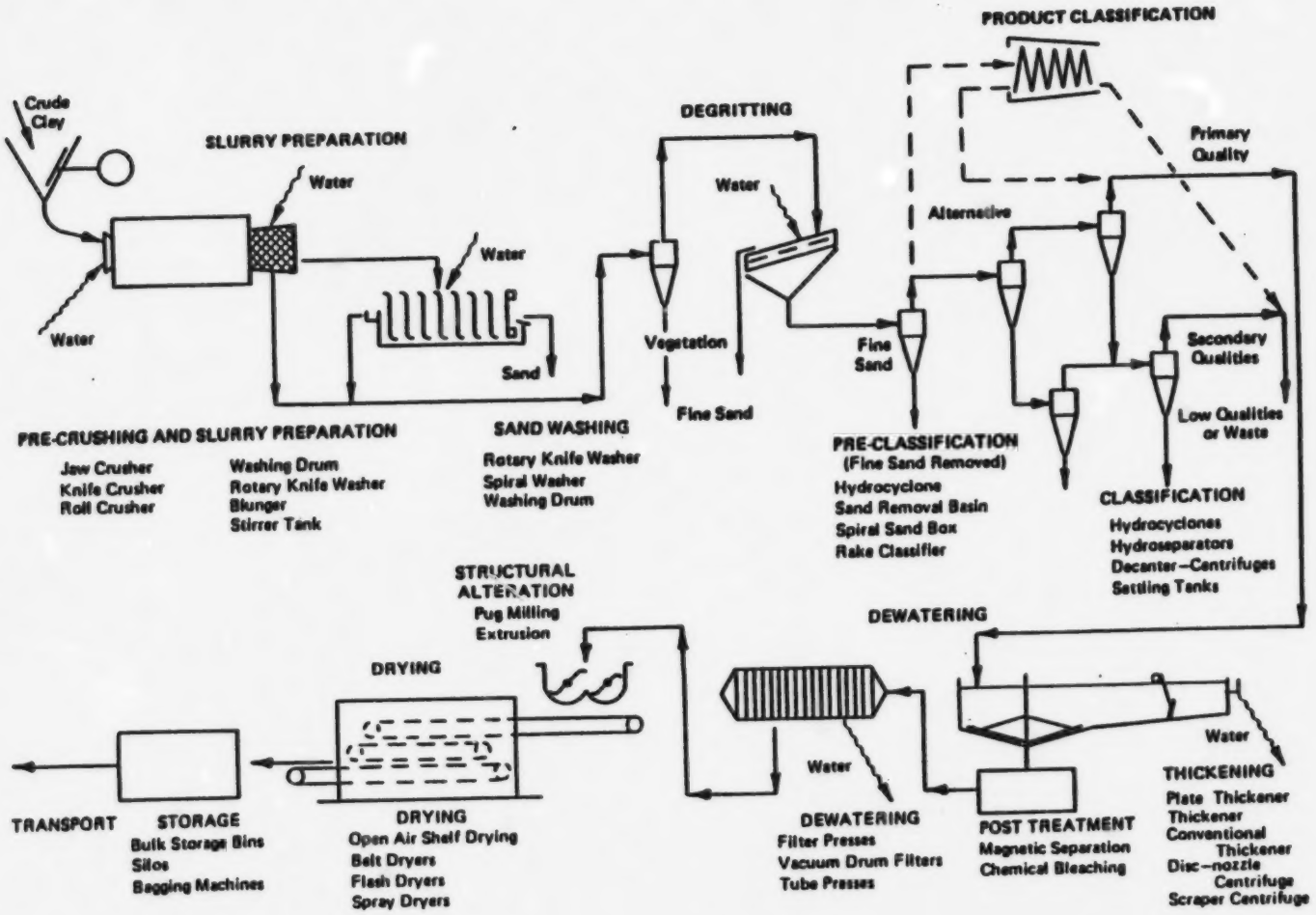

Figure 4-2: Flowsheet for a composite optional kaolin processing plant (Guillet and Kriens, 1984).

Brightness of kaolin tends to be higher in residual deposits rather than in sedimentary deposits. Iron oxides or hydroxides can coat and discolour the particles. Chemical bleaching, occasionally in combination with electromagnetic separation, can be used to increase the brightness of the product. Common bleaching agents include sodium or zinc hydrosulphite or similar reducing agents and are used in a low pH environment. The electromagnetic separation removes very fine iron or titanium particles.

Kaolin has a high ratio of mean diameter to thickness which reflects the platy, or flaky, habit of the mineral. Individual kaolin plates often occur as a "stack" which is held together by high "cohesive forces". As a result, what appears to be coarse grains are in fact stacks of fine kaolin flakes. Techniques have been developed for the delamination or separation of the individual kaolin plates in order to produce a product of finer particle size. These techniques all involve high shear forces and are therefore energy intensive. Initially, the finer particles (<2 microns) are removed and the coarser material retained for delamination. One technique involves high shear agitation of kaolin slurry with nylon pellets. Another technique involves pug milling at 75-85% solids with subsequent extrusion through a die having holes ranging from 0.5 to 12mm in diameter. The delamination process increases the yield of paper coating grades (finer particle sizes) and produces a product of high brightness since the stacked platelets have not been exposed to contamination and are clean and white.

The kaolin slurry is dewatered at the conclusion of the beneficiation cycle. A flocculant can be added to cause the kaolin to settle and produce a thickened slurry. The

flocculant can be an acid, a salt of an acid, a neutral salt, or an organic flocculant. Filter presses, or vacuum drum continuous belt, or tube-type filters are used to produce a filter cake containing about 25% water. The filter cake is dried using belt, spray or flash dryers or similar techniques. Because of the high energy costs associated with drying, some paper coating grade material is shipped as a slurry (70% solids) and arrives ready for use in the paper coating process.

4.2.2.2.2 Dry Processing

Dry processing methods can often be used to produce clays for paper filling, ceramic, and rubber filling applications from sedimentary deposits. Kaolin from residual deposits is usually always treated by wet processing methods. Wet processing is mandatory for paper coating grades of kaolin.

Dry processing of kaolin usually requires selective mining and blending to obtain suitable feedstock. Lump kaolin clay is reduced in size using shredders or other suitable means. The clay is then dried in a rotary dryer and pulverized or ground. Roller mills equipped with internal classifiers can be used to discharge coarse grit and other contaminants. Classification can also be accomplished by air classification after pulverization. Products are stored in large silos from where they can be shipped in bulk or in bags by rail or truck.

Kaolin produced by dry processing usually closely reflects the properties of the crude kaolin. The dry process is simple and relatively inexpensive. In general, it results in products of lower quality and value than those

produced by wet processing.

4.2.2.2.3 **Other Treatments**

Kaolin products produced by wet processing can be calcined. Calcination, at temperatures up to 1,000°C, drives off the water of hydration resulting in the alteration of several of the physical properties of the kaolin. The physical degeneration of the molecular structure of the kaolin caused by the release of water, in a manner similar to delamination yields a product of increased brightness. The reduced water content results in a harder, more abrasive product with reduced oil absorption and increased electrical resistivity.

Calcined kaolins are becoming popular as an extender or spacer for high priced titanium dioxide in many industrial applications, in particular paints, paper and plastics. Calcined kaolin provides good hiding power and opacity in coatings, and good electric resistivity in plastics used for such purposes as cable and wire coatings.

As is the case with many mineral fillers, surface treatment with specially developed organic chemicals can be used to improve the performance of air floated, water washed or calcined kaolins. Water washed or calcined kaolins are the types most often treated. Stearates and various types of silanes are normally used to improve dispersion of the kaolin particles through the material to which it is being added and to improve the bonding of the mineral particles to that material. The surface coating of minerals is a specialized technique, and most manufacturers develop their own methods and consider them proprietary.

4.3 Utilization and Consumption

The bulk of the North American kaolin filler market is comprised of four major product sectors: paper, paint, plastics and rubber. An additional six product sectors: adhesives, carpet backing, putty caulks and sealants, printing inks, fertilizers and pesticides in total make up a minor proportion of the kaolin consumed in filler applications. Kaolin is also used in several major non-filler applications which will not be dealt with in this report to any extent. These applications include ceramics, fiberglass and refractory brick.

In an area which approximates the study area, the estimated (Guillet and Kriens, 1984) annual market for kaolin is:

Paper	2,200,000	(86.1%)
Plastic and rubber	200,000	(7.8%)
Paint	90,000	(3.5%)
Adhesives	40,000	(1.6%)
Inks	15,000	(0.6%)
Others	10,000	(0.4%)
TOTAL	2,555,000	

The range of grades of kaolin fillers is necessitated by the range of applications for which they are used. The various grades result from processing and beneficiation options being applied to raw kaolin which itself varies from deposit to deposit. The net result of these variables is a pricing scheme which varies considerably. Table 4-3 lists the overall average prices, by product process, paid for kaolin filler which was sold to all users in the United States in 1986.

The prices quoted in Table 4-3 are based solely on total volume of product sold and its total value. In detail, as will become evident with the quotation of actual product prices specific to the various filler applications, prices vary markedly. These variations depend upon brightness, particle size and the degree of specialty processing such as calcination and/or surface treatment to which the product has been subjected.

Product Process	Average Price* $Can./Tonne
Air floated	$ 70.00
Delaminated	85.00
Water-washed	135.00
Calcined	190.00

*based on the total quantity and value of all transactions competed in the United States in 1986.

Table 4-3: Average Price of Kaolin in the United States (United States Bureau of Mines, 1986)

4.3.1 Paper

4.3.1.1 Applications

The paper industry is the largest consumer of kaolin, accounting for almost 50% of the United States consumption. With the exception of a few specialty grades, kaolin is the main pigment used in almost all paper applications. Kaolin accounts for over 80% of the fillers and 90% of the coatings used in the North American paper industry. Kaolin

production trends mirror those of coated paper.

Several types of paper contain mineral fillers to either reduce cost by displacing more expensive fibre, or to incorporate certain physical properties. Printing and writing paper use the largest quantities of filler whereas cheaper varieties such as newsprint often do not contain mineral filler. The use of fillers in paper boards is restricted to white liner board and coated board. The higher grades of printing and writing papers use mineral fillers to obtain a higher opacity, good ink receptivity, improved printing characteristics and better textural properties. The specifications of any mineral intended for use as a paper filler include:

1. High reflectance in all wavelengths of light to give maximum brightness and whiteness.
2. Very high refractive index so as to increase opacity.
3. Chemical inertness and insolubility.
4. Freedom from impurities, especially grit.
5. Particle size distribution of approximately 0.3 microns (i.e. half the wavelength of light).
6. A soft and non-abrasive nature.
7. A surface flexible enough to form either a matte or glass finish with processing.
8. Good retention characteristics in the cellulose fibre web.
9. A low specific gravity.
10. A competitive price.

Paper coatings are applied to the surface of papers to improve the receptivity of ink, mask the inconsistencies on the original paper, produce a high grade product, apply a moisture-resistant film, reduce abrasion and limit fluffing

(the volume increase in a stack of paper due to air retention within an open fibre web).

Kaolin goes further than any of the common filler minerals in fulfilling the requirements outlined to make a perfect paper filler and coating. As a result, no other mineral or group of minerals approaches kaolin's importance to the paper industry.

The weight of kaolin used for paper coating can be as much as 15 to 25% of the weight of the paper. Paper coatings made with delaminated kaolin are lighter in weight and hence particularly useful for lightweight papers. Delaminated kaolin commonly comprises 15 to 23% of total paper weight in coating applications. Depending on type or grade of paper and other fillers used, kaolin is used in amounts of 5 to 15% of total paper weight.

Partly calcined kaolin is used by the paper industry primarily as an extender and partial substitute for more expensive titanium dioxide.

4.3.1.2 Specifications

For paper coating, water washed, delaminated and calcined kaolins are used, whereas for paper fillers, water washed or dry processed air floated kaolins are used. The specifications for these grades of kaolin have been delineated on Tables 4-1A and B.

Paper coating is usually performed in two steps, a base coat, usually a coarser grade, followed by a top coat of the finer and possibly higher brightness grade. The Number 2 and 3 coating grades are used for "publication" grade paper

while the Number 1 and Fine Number 1 grades are used in special applications requiring high gloss, brightness and smoothness.

4.3.1.3 Price Range

Kaolin is sold in 22.7 kg bags, dry bulk or as a 70% solids predispersed slurry. Calcined kaolin is sold in 22.7 kg bags.

Kaolin purchased by the paper industry commends a premium price due to the industry's stringent specifications. Table 4-4 lists the prices, by grade, for kaolin purchased by the paper industry.

Product Grade	Price $Can/Tonne (f.o.b. Georgia)
Uncalcined:	
No. 1 coating grade, bulk	143
No. 2 coating grade, bulk	110
No. 3 coating grade, bulk	107
No. 4 coating grade, bulk	103
delaminated, water washed, av. 1 micron, bulk	403
Calcined:	
water washed, paper grade, bags	644

Table 4-4: Price of kaolin grades used by the paper industry (Chemical Marketing Reporter, 1988).

4.3.1.4 Consumption Levels

Paper represents the largest consuming industry, in terms of filler value, of mineral fillers and coatings used

in North America. Figures presented by Guillet and Kriens (1984) suggest that within an area which approximates the study area, the annual consumption of kaolin by the paper industry represents 86% of the total annual consumption of kaolin used in all applications. The absolute figures presented by Guillet and Kriens are inflated relative to those expected for the study area being discussed herein. Their figures included the Great Lakes states (Minnesota, Wisconsin, Illinois, Indiana, Michigan and Ohio) and Wisconsin is a major paper producing state. The validity of their relative percentages of kaolin utilization by the various consuming industries, however, is thought to be reasonable.

In the Canadian sector of the study area, the paper industry consumes approximately 150,000 tonnes of kaolin. Consumption by province is given in Table 4-5.

	NFLD.	N.S.	P.E.I.	N.B.	QUE.	ONT.
Year	'83	'83	'83	'87	'83	'83
No. of Mills	2	3	0	7	25	27
Tonnes Utilized (Dry)	0	0	0	>63,000	28,260	55,112

Sources: 1983 Figures - Prud'homme (1986)
1987 Figures - Davis (1987)

Table 4-5: Kaolin consumption by the paper industry in the Canadian sector of the study area

Available statistics detailing the consumption of kaolin fillers and coatings by the paper industry in the United States do not permit the breakdown of national

consumption figures as readily as do the Canadian statistics. The size of the potential U.S. paper industry market for kaolin in the study area can be quantified in a manner similar to that used for calcium carbonate. Table 3-13 presents statistics which quote the number of paper mills operating in the study area, their relative production capacities and the value of their shipments of paper and allied products. The implications of these statistics presented on Table 3-13 can be applied to kaolin utilization as they have been to calcium carbonate in Chapter 3.0.

In an effort to further define kaolin markets in the study area, statistics relevant to the production of clay coated printing and converting papers are provided in Table 4-6. The states of Maine, New York and Pennsylvania produce one-third of total U.S. production in terms of product value. The state of Maine leads the nation with just less than one-quarter of the value of total production. The state of Wisconsin's production is included in Table 4-6 because it is one of the four states producing an economically significant proportion of the total U.S. production at just under one-fifth of the total.

The kaolin consumption figure (2,200,000 tonnes) generated by Guillet and Kriens (1984) for an area which approximates the study area includes Wisconsin's production of clay bearing papers. That figure, reduced by 20% to exclude Wisconsin (see Table 4-6), suggests that approximately 1,760,000 tonnes of kaolin are consumed by the paper industry in the study area. Table 4-6 also indicates that the United States portion of the study area accounts for about one-third of the value of clay coated printing and converting papers in the United States.

	Value of Shipments ($ x 10^6)	% of National Total
Maine	886.0	23
New York	214.6	6
Pennsylvania	144.5	4
Wisconsin*	728.7	19
U.S. Total	3,787.3	100

$ - U.S. dollars

Source: U.S. Department of Commerce; 1982 Census of Manufacturers

*Wisconsin is not within the study area

Table 4-6: Value of clay coated printing and converting papers (SIC 26213) from those states which produce an economically significant proportion of national production.

4.3.2 Plastic

4.3.2.1 Applications

Kaolin is used in plastics primarily as a bulk filler to reduce the quantity of higher priced resin which must be used. Water washed, delaminated and calcined kaolins are used in plastics and in many cases each have specific product applications.

Water washed kaolin is used in polyester and phenolics, both thermoset plastics used in producing moulded goods such as auto parts. In polyester, it is used in bulk and sheet moulding compounds. In addition to functioning as a resin extender it aids in viscosity control of the mixture. Kaolin has good moulding characteristics and improves the surface quality of plastic parts such as auto

body components and boats. In phenolics, both water washed and air floated kaolin are used as a replacement for short fibre asbestos. Kaolin improves the dimensional stability, electrical properties, water resistance and also provides some reinforcement. Loading levels can vary considerably and to some extent depend on the total filler loadings employed since kaolin is typically used in combination with other fillers. Typical loadings range from 5 to 30 parts of kaolin per 100 parts of polymer.

Delaminated kaolin is not frequently used in plastics. It does, however, have a better colour than air floated or water washed kaolin and also has greater reinforcing properties in some properties in some polymer systems. Increased tensile strengths have been reported as a result at the use of delaminated kaolin.

Calcined kaolin is a commonly used filler in polyvinyl chloride (PVC) wire and cable coatings. It imparts excellent electrical insulation properties to PVC and so can be termed a functional mineral filler in this application. Calcined kaolin can be used at loading levels ranging from 10 to 30 parts of filler per 100 parts of resin.

Water washed, delaminated or calcined kaolins are used as feed stock for the production of surface treated kaolin. Surface treated grades are used primarily in nylon and less frequently in low density polyethylene. In nylon, the kaolin filler functions not only as a resin extender but it also improves a number of physical properties such as stiffness, mould shrinkage and sensitivity to moisture. It also reduces stress cracking. In polyethylene, the use of surface treated kaolin improves heat deflection. Surface

treatment usually consists of coating the kaolin with polyfunctional silanes. Most nylons are processed at high temperatures, requiring surface coatings that will be stable at the processing temperatures employed. Surface treated calcined kaolin is used in nylon at 20 to 40 parts of filler to 100 parts of resin. (See Section 2.3.2.1 for a background discussion on plastics and the use of fillers in the plastic industry).

4.3.2.2 Specifications

The specifications for the various grades of kaolin have been delineated on Tables 4-1A and B.

Water washed kaolin is usually used in polyesters and either water washed or air floated grades can be used in phenolics. Air floated grades with low grit content are often chosen because of their lower cost although in applications where abrasiveness can not be tolerated, water washed grades must be used. The poorer colour of air floated kaolin is a deterrent because it can affect the pigmentation of coloured plastic items.

4.3.2.3 Price Range

Water washed kaolin grades used in plastics are similar to the grades used in paper. Air floated grades, however, are more commonly used in certain plastics than in paper. The prices quoted on Table 4-7 reflect these applications. The price structure presented for surface treated kaolin reflects the complexity and cost of their production. Kaolin purchases by the plastics industry are best suited to 22.7 kilogram bag lots; prices are quoted only for bagged lots per tonne.

4.3.2.4 **Consumption Levels**

As had been noted in the presentation of consumption

Product Grades	Price* $ Can / Tonne
Air floated	$ 75 - $ 94
Water washed	$194 - $280
Calcined	$312 - $375
Surfaced treated	$525 - $725

*range reflects the degree of processing, brightness and particle size (f.o.b. Georgia). Price range is based on 1984 values but 1988 spot prices are within the range.

Table 4-7: Price of kaolin purchased by the plastics industry in the northeastern U. S. and eastern Canada (Guillet and Kriens, 1984; Metal Economics Group, 1988)

statistics for calcium carbonate, available statistics for the plastics and rubber industries tend to be grouped together. In fact, Canadian statistics for kaolin utilization include paint with plastic and rubber.

As a group, the plastics and rubber industries represent the second largest consuming group, after paper, for kaolin. Relative to the magnitude of the paper market for kaolin, however, all other consuming industries are small. Plastics and rubber comprise approximately 10% of the total market in North America.

The methods used for the assembly of statistics on the consumption of kaolin in Canada do not permit a breakdown by industry. The figures reflect the total importation of kaolin into the country by the plastics, rubber and paint

industries. These figures are quoted on Table 4-8.

	Nfld.	N.S.	P.E.I	N.B.	Que.	Ont.
Tonnes	36	62	0	2,404	86,778	160,750

Table 4-8: Kaolin imports into Canada for consumption by the plastics, rubber and paint industries in 1985 (Prud'homme and Francis, 1987)

Available statistics detailing consumption of raw materials by the plastics industry in the United States do not permit the breakdown of the statistics to the point where kaolin consumption within the study area can be quantified. The size of the potential U.S. plastics industry market for kaolin in the study area can be estimated in a manner similar to that used for calcium carbonate. The figures quoted on Table 3-8, provide data relevant to the location by state and the size of the potential market for kaolin fillers in the plastics industry. The size of the potential market is quantified by quoting the number of firms manufacturing products which may contain kaolin fillers and the value of shipments made by those firms. The statistics, due to their method of compilation, overlap slightly with those quoted for the rubber industry with the result that the figures quoted in Table 3-8 are inflated somewhat from pure plastics industry figures.

The study area includes 27.9% of the U.S. plastics industry, in terms of number of firms in production. These firms ship 25.7% of the total value of plastics products produced in the U.S. Guillet and Kriens (1984) estimate of total U.S. kaolin filler consumption incorporates both the plastics and rubber industries. They estimate that consumption figure to be 300,000 tonnes annually. In order to estimate kaolin filler consumption for these industries

within the study area it is therefore necessary to have an estimate of the size of the rubber industry within the study area. This estimate follows in Section 4.3.3.4.

In terms of kaolin consumption by the plastics industries, the states of Massachusetts, New Jersey, New York and Pennsylvania account for the bulk of the production and therefore are expected to account for the bulk of the kaolin consumption by these industries.

4.3.3 Rubber

4.3.3.1 Applications

Kaolin used in rubber is classified as either hard or soft. These terms are employed in the rubber industry to distinguish certain critical properties. Kaolin may be used with other natural or synthetic fillers.

Hard kaolin is a functional filler with reinforcing properties in rubber. It is used in high performance rubber such as automobile tires, footwear and cable end wire coatings. Soft kaolin is used as a processing aid or as a filler in rubber goods not requiring reinforcement such as many household goods. Calcined kaolin produced form either hard or soft kaolins is used in rubber wire and cable coatings to improve the dialectic properties of the product. The use of surface treated kaolin improves dispersion, filler particle bonding and enhances its reinforcing properties in rubber. The benefits from surface treated kaolin are improved elasticity of the rubber and decreased deformation.

Kaolin loading levels vary widely, depending upon application. In footwear, loadings of hard kaolin range from 30 to 80 parts of kaolin per 100 parts of rubber while in automobile tires loadings are 15 to 30 parts per 100. In soft rubber goods, soft kaolin is added at rates of 100 to 200 parts per 100 parts of rubber. Calcined kaolin is added to wire and cable coatings at rates between 50 to 150 parts per 100 parts of rubber.

4.3.3.2 **Specifications**

The specifications for the various grades of kaolin have been delineated on Tables 4-1A and B.

Hard rubber grades of kaolin are produced from sedimentary deposits while soft rubber kaolins may be produced from either residual or sedimentary deposits while soft rubber kaolins may be produced from either residual or sedimentary deposits. The hard kaolins are finer than the soft grades. Kaolins used in rubbers are generally air floated or water washed grades although some calcined and surface treated grades are used in special applications.

Soft air floated kaolins generally have a larger average particle size and lower brightness than water washed grades. Grades with low grit content are preferred. Hard air floated kaolin is finer than soft air floated kaolin but generally is also of low brightness. Hard air floated kaolin is the most common grade of kaolin used in rubber.

Water washed kaolins of fine particle size exhibit reinforcing properties similar to hard air floated grades but they have better colour, lower abrasiveness and fewer impurities.

Calcined kaolins produced from air floated hard or soft kaolins, used in wire and cable coatings, tend not to exhibit high brightness. Surface treated kaolin is produced by treating water washed or calcined grades with silanes.

4.3.3.3 Price Range

Kaolin purchases by the rubber industry are best suited to 22.7 kilogram bagged lots; prices are quoted on Table 4-9 only for bagged lots per tonne.

4.3.3.4 Consumption Levels

Available statistics for the plastics and rubber industries tend to be grouped together. The Canadian statistics for kaolin utilization include paint with plastic and rubber.

As a group, the plastics and rubber industries represent the second largest consuming group, after paper, for kaolin. Relative to the magnitude of the paper market for kaolin, however, all other consuming industries are small.

The methods used for the assembly of statistics on the consumption of kaolin in Canada do not permit a breakdown by industry. The figures reflect the total importation of kaolin into the Canada by the plastics, rubber and paint industries. These figures are quoted on Table 4-8.

Based on United States Department of Commerce figures the study area includes 23.4% of the U.S. rubber industry, in terms of number of firms in production (see Section 3.3.7.4). These firms ship approximately 8% of the total

value of rubber products produced in the U.S. This wide variation is due in large part to the fact that there are relatively few firms (7.3% of total number of tire and tube manufacturers in the country) producing tires and tubes in the study area. These two products account for approximately 50% of the value of all shipments of rubber products in the U.S. and tend to be manufactured by relatively few firms (9.3% of total number of rubber fabricators in the country).

Product Grades	Price* $ Can / Tonne
Air floated, hard and soft	$ 50 - $ 94
Water washed	$188 - $225
Calcined	$288 - $400
Surfaced treated - water washed	$212 - $300
- calcined	$500 - $600

*range reflects the degree of processing, brightness and particle size (f.o.b. Georgia). Price range is based on 1984 and 1986 values but 1988 spot prices are within the range.

Table 4-9: **Price of kaolin purchased by the rubber industry in the northeastern U. S. and eastern Canada (Guillet and Kriens, 1984; Dickson, 1986; Metal Economics Group, 1988).**

Guillet and Kriens (1984) estimate the total U.S. kaolin filler consumption by the plastics and rubber industries to be 300,000 tonnes annually. The study area produces approximately 25% of the total value of plastics products and 8% of the total value of the rubber products produced in the U.S. Based on these figures, the plastics and rubber industries combined in the U.S. sector of the study area consume approximately 51,000 tonnes of kaolin per year.

4.3.4 Paint

4.3.4.1 Applications

The paint industry uses kaolin as a pigment extender. Water washed, delaminated and calcined grades of kaolin are used.

Water washed kaolins are used in flat wall paints as a pigment extender in conjunction with other mineral extenders. Kaolin is easy to disperse in water, aids in viscosity control and improves brushability and smoothness of the paint film. Kaolin's platy crystal structure contributes to its hiding power.

Delaminated kaolins contribute to paint's hiding power, flow characteristics, film smoothness, stability and tint retention.

Calcined kaolins in paint are used to reduce the requirements for more costly titanium dioxide the prime pigment in paints. It is used in water based paint systems, mostly in flat latex wall paints. The coarser grades of calcined kaolin are also used in the production of traffic paints; its high abrasiveness aids in the production of flat nonglare paints with good resistance to wear.

All grades of kaolin are added to paints at levels between 50 and 150 grams per litre of paint depending upon the type of paint being produced and the required physical properties. (See Section 2.3.1.1 for a background discussion of paint and the use of fillers in its manufacture).

4.3.4.2 Specifications

The specifications for the various grades of kaolin have been delineated on Tables 4-1A and B.

Dry processed kaolins are generally not used by the paint industry because of their low brightness, coarse particle size and potential presence of water soluble salts. Generally the paint industry prefers kaolins of high brightness and fine particle size.

Delaminated kaolins possess particles with diameter to thickness ratios of up to 40:1. Such particles exhibit good brightness and particle shape characteristics.

The nature of the feed material, the particle size and variations in calcination temperature yields calcined kaolin products of varying physical properties. Generally calcined kaolins have higher brightness, improved electrical resistance, increased abrasiveness and lower oil absorption relative to the fed material. Water washed or delaminated kaolin is the usual feed stock used.

4.3.4.3 Price Range

Kaolin purchases by the paint industry are received in bag, bulk or slurry form. The prices paid for the various kaolin products required are reflected by these listed on Table 4-10.

4.3.4.4 Consumption Levels

The paint industry is the second largest single consuming industry, by value, after paper of mineral fillers

in North America.

The method used for the assembly of statistics on the consumption of kaolin in Canada do not permit a breakdown by industry. The figures reflect the total importation of kaolin into Canada by the plastics, rubber and paint industries. Those figures are quoted on Table 4-8. The consumption figures quoted in Section 4.3 suggest that the paint industry consumes approximately one-third, by weight, of the kaolin used by the plastics, rubber and paint industries. Consumption of kaolin by the plastics and rubber industries within the study area is estimated at 51,000 tonnes (Section 4.3.3.4). This suggests that consumption by the paint industry within the study area is approximately 17,000 tonnes.

Product Grades	Price* $ Can / Tonne
Water washed (22.7 kg bag)	$163 - $275
Delaminated:	
- brightness 85-87 (bulk)	$188
- brightness 89-91 (22.7 kg bags)	$338
Calcined (22.7 kg bags)	$300 - $625

*range reflects the degree of processing, brightness, and particle size (f.o.b. Georgia). Price range based on 1984 and 1986 values but 1988 spot prices are within the range.

Table 4-10: **Price of kaolin purchased by the paint industry in the northeastern U. S. and eastern Canada (Guillet and Kriens,, 1984; Dickson, 1986; Metal Economics Group, 1988)**

4.3.5 Adhesives

4.3.5.1 Applications

The adhesives industry uses several different types of fillers, all referred to as inert or inactive extenders. Kaolin makes up the bulk of the fillers used by the industry.

Air floated kaolin finds its third largest application in adhesives after rubber and paper. It is the grade most commonly used in low cost adhesives such as in construction, tile and panelling adhesives. Kaolin improves the trowelling and flow properties of the adhesives, but primarily it serves as a filler (cost reducer) without altering product characteristics.

Water washed kaolin is used in synthetic, vegetable or rubber based adhesives. Its prime function is to reduce cost but it also controls viscosity and acts as a flow agent.

Minor amounts of surface treated kaolin is used in adhesives. They act as dispersion and suspension aids in liquid adhesive.

4.3.5.2 Specifications

The specifications for the various grades of kaolin have been delineated on Tables 4-1A and B.

Air floated kaolins of high purity, low grit content and fine particle size are preferred by the adhesive industry. Where colour is important water washed kaolins

are used. Water washed kaolins used are commonly grades with high average particle size and low brightness. Surface treated kaolins used by the adhesives industry tend to be very fine (0.2 - 0.4 micron).

4.3.5.3 Price Range

Kaolin purchases by the adhesive industry are best suited to 22.7 kilogram bagged lots; prices are quoted in Table 4-11 only for bagged lots per tonne.

Product Grades	Price* $ Can / Tonne
Air floated	$ 63- $ 88
Water washed:	
- 2-3 um; brightness 80-84	$163
- 4-5 um; brightness 80-84	$213
Surfaced treated	$500 - $750

*range reflects the degree of processing, brightness and particle size (f.o.b.Georgia) based on 1984 and 1986 values.

Table 4-11: Price of kaolin purchased by the adhesives industry the northeastern U.S. and eastern Canada (Guillet and Kriens, 1984; Dickson, 1986).

4.3.5.4 Consumption Levels

Consumption figures for kaolin in the manufacture of adhesives in Canada are not available. Specific figures for the U.S. sector of the study area are also unavailable. However, it is possible to quantify the U.S. market potential. Table 4-12 quotes the number of firms manufacturing adhesives which may contain kaolin fillers and the value of shipments made by those firms.

Examination of the figures quoted on Table 4-12 indicates that 177 firms, or 25.9% of the total number of manufacturers of adhesives in the United States are located within the U.S. sector of the study area. These firms shipped products valued, in 1982, in excess of $US 733.0 million or approximately 25.7% of the U.S. total. The product value figures are approximate since the value of shipments from New Hampshire was withheld although New Hampshire has only 0.7% of the total number of firms in

	No. of Firms	% of Totals	Value of Shipments ($US x 10^6)	% of National Totals
Connecticut	12	1.8	74.2	2.6
Delaware	--	--	--	--
Maine	--	--	--	--
Massachusetts	33	4.8	125.3	4.4
New Hampshire	5	0.7	w	w
New Jersey	58	8.5	301.5	10.6
New York	42	6.1	134.1	4.7
Pennsylvania	27	4.0	97.9	3.4
Rhode Island	--	--	--	--
Vermont	--	--	--	--
U.S. Sector of Study Area Totals	177	25.9	733.0	25.7
National Totals	683	100	2,856.7	100

Source: 1982 Census of Manufacturers, U.S. Department of Commerce

TABLE 4-12: Number of manufacturers and value of shipments of adhesives and sealants (SIC 2891) in the U.S. sector of the study area.

the U.S. manufacturing adhesives. These figures suggest that the U.S. sector of the study area produces approximately 26% of the adhesives manufactured in the U.S.

It is therefore assumed that the area consumes approximately 26% of the kaolin used by this industry in the U.S. Examination of the same figures for the balance of the states included within the Guillet and Kriens (1984) study area (Illinois, Indiana, Michigan, Minnesota, Ohio and Wisconsin) indicates that these states themselves possess an adhesives industry of similar magnitude. This suggests that Guillet and Kriens consumption figures for the U.S. portion of their study area are double those for this study area. Figures are unavailable for Canada, but, assuming the usual 10% factor for comparing U.S. and Canadian statistics, the fact that the Canadian sector of the Guillet and Kriens study area is effectively the same as that for this study and that the bulk of Canadian industrial products are manufactured in central Canada (within the study area), the market for kaolin by the adhesives industry in the study area is approximately 19,000 tonnes annually. This is based upon Guillet and Kriens' figures of 65,000 tonnes of kaolin fillers for the entire North American adhesives industry and 40,000 tonnes for their midwestern United States and central Canada study area.

4.3.6 Others

4.3.6.1 Applications

Kaolin fillers are used in several other products manufactured within the study area. The quantities of kaolin consumed by these products is small relative to those previously discussed. These products include printing inks, carpet backing, putty, caulks and sealants, fertilizers and pesticides.

In printing inks kaolin controls viscosity and flow properties, primarily in publication and flexographic inks.

Kaolin is used, although in decreasing amounts, in natural rubber and foamed latex carpet backing. It is being displaced by other less costly fillers with lower binder demand such as calcium carbonate.

The addition of kaolin to putty, caulks and sealants is primarily for the reduction of product cost. Kaolin does, however, improve the application properties of the product. Poor colour and high binder demand for air floated kaolin makes calcium carbonate the filler of choice for these applications. Water washed kaolin is used in premium products such as bath tub caulk and other water based products to aid viscosity, smoothness and ease of extrusion from tube or cartridges. High quality white coloured putty, caulks and sealants incorporate calcined kaolin as a pigment extender with titanium dioxide.

Air floated kaolins coated with aminos are used in fertilizers as anti sticking and flow conditioners.

Kaolin is used as a carrier or diluent for pesticides and insecticides for crop dusting and similar applications.

4.3.6.2 Specifications

Printing inks require high brightness water washed kaolins.

Carpet backing uses air floated and medium to fine particle size water washed kaolins.

Air floated, water washed and calcined grade of kaolin are used in putty, caulks and sealants. Products of low average particle size (< 0.5 mm) with a brightness of at least 85 are used.

Coarse, air floated kaolins coated with aminos are used as fertilizer fillers.

Dry processed kaolin with good absorptive capacity is used in pesticide.

4.3.6.3 Price Range

The various small volume kaolin user industries cover a fairly broad spectrum of filler specifications. This variation is illustrated by the prices quoted on Table 4-13.

Industry / Product Grade	Price* $ Can / Tonne (22.7 kg bagged lots)
Carpet backing:	
- air floated	$ 63 - $ 75
- water washed	$163 - $188
Putty, caulks and sealants:	
- air floated	$ 59 - $ 81
- water washed	$250 - $438
- calcined	$300 - $500
Fertilizers:	
- air floated	$ 88 - $125
Pesticides:	
- dry processed	$ 50 - $ 69

*range reflects the degree of processing, brightness and particle size (f.o.b. Georgia). Price range is based on 1984 and 1986 values but 1988 spot prices are within the range.

Table 4-13: Price of kaolin purchased by the carpet, putty, caulk and sealant, fertilizer and pesticide industries in the northeastern U.S. and eastern Canada (Guillet and Kriens, 1984; Dickson, 1986; Metal Economics Group, 1988).

4.3.6.4 Consumption Levels

The consumption figures quoted in Section 4.3 for the various small volume kaolin user industries total 25,000 tonnes; printing inks taking 15,000 tonnes alone. These figure were generated by Guillet and Kriens (1984) for a study area which includes the bulk of the current study area but also included additional states in its U.S. sector.

Printing inks consume the bulk of the kaolin used by the various "other" applications. Again statistics which can be utilized to directly quantify kaolin consumption, in this instance, by the printing ink manufacturing industry are unavailable. Within the U.S. sector of the study area, however, it is possible to quantify market potential. Table 4-14 quotes the number of firms manufacturing printing inks which may contain kaolin fillers and the value of shipments made by those firms.

	No. of Firms	% of Totals	Value of Shipments ($US x 10^6)	% of National Totals
Connecticut	--	--	--	--
Delaware	--	--	--	--
Maine	--	--	--	--
Massachusetts	17	4	23.1	1.5
New Hampshire	--	--	--	--
New Jersey	54	12	W	W
New York	27	6	W	W
Pennsylvania	20	4	57.3	3.6
Rhode Island	--	--	--	--
Vermont	--	--	--	--
U.S. Sector of Study Area Totals	118	25	>80.4	>5.1
National Totals	467	100	1,571.5	100

Source: U.S. Department of Commerce; 1982 Census of Manufacturers

TABLE 4-14: Number of manufacturers and value of shipments of printing ink (SIC 2893) in the U.S. sector of the study area.

Examinations of the figures quoted on Table 4-14 indicates that 118 firms, or 25% of the total number of manufacturers of printing inks in the United States are located within the U.S. sector of the study area. These firms shipped products valued, in 1982, in excess of $U.S. 80.4 million. The value of shipments of printing inks from the states of New Jersey and New York has been withheld by the U.S. Department of Commerce and does not enable the establishment of a percentage of total value of U.S. production from these states or the study area. New Jersey and New York represents a total of 18% of the number of firms in the U.S. manufacturing printing inks, a substantial proportion. Although these two states have fairly large numbers of firms in this industry, the value of their production is still withheld suggesting that each state hosts a small number of large ink producers. The figures portraying the relative size of the U.S. sector of the industry based upon value of shipments is therefore thought to be unreliable. The size of U.S. sector of the industry based upon the number of firms suggests that 25% of the U.S. industry exists within the study area.

Examination of the same figures for the balance of the states included within the Guillet and Kriens (1984) study area (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin) indicates that these states themselves possess a printing ink industry of similar magnitude to that of the study area currently being evaluated. Based upon the conclusions, relative to market size, arrived at in Section 4.3.5.4 (Consumption-adhesives), which appear to hold true for printing inks, the printing ink industry within the study area consumes approximately 7,000 tonnes annually of kaolin.

Consumption of kaolin fillers by the sundry other consuming industries has been estimated utilizing the statistics and reasoning similar to those applied in quantifying the adhesives and printing ink figures. This suggests that approximately 5,000 tonnes annually of kaolin are used by the carpet backing, putty, caulks and sealant, fertilizer and pesticide industries.

4.4 Competitive Materials

Kaolin fillers compete with a number of fillers in many of its applications. The competition may be for either technical or economic reasons. Kaolin is clearly the filler of choice in paper manufacturing particularly given its compatibility with acid sizing.

Calcium carbonate is the principal competition for kaolin. Conversion of paper mills from acid to alkaline sizing could result in a shift to calcium carbonate fillers because of its lower price and greater whiteness. For these same reasons, price and whiteness, calcium carbonate is the filler of choice in paints although kaolin has better flow characteristics and covering power. Precipitated calcium carbonate competes with kaolin in paper coating because of its greater whiteness although kaolin has a cost advantage.

Precipitated silica gives better reinforcing properties to rubber and improved light scattering properties in paper than kaolin. These enhanced properties are due to precipitated silica's extremely fine particle size relative to kaolin. The positive features are offset somewhat by kaolin's lower cost.

Talc competes with kaolin in paint, given talc's better brightness, hiding and spreading properties. Talc also competes in putty, caulks and sealants because of its ability to improve flow properties.

4.5 Trends and Market Potential

Increased utilization of calcium carbonate fillers at the expense of kaolin in paper manufacturing depends in large part on the rate of conversion of mills from acid to alkaline or neutral sizing. The impetus for conversion in the coming years will likely come from steadily increasing fibre costs. This potential negative impact on kaolin consumption will at least be partly alleviated by improved kaolin beneficiation techniques which will yield a more competitive product. Successful application of high-intensity magnetic separators to kaolin beneficiation yield a whiter, more pure product as well as expanding the kaolin reserve base in the southern U. S.

Surface treated kaolin, as are surface treated calcium carbonate and talc, is becoming increasingly popular in various plastics applications. Improved dispersion properties of the treated filler suggests that this application will expand as research and experience grows. Similarly, as a result of this trend to use kaolin as a functional filler, surface treated kaolins are gaining popularity in rubber applications as well.

Expanding kaolin production in Brazil and Australia could result in over supply on world markets and depress prices somewhat. Sharp price drops, however will likely be prevented by high production costs.

The possibility of kaolin production beginning in the Moose River Basin of Northern Ontario could impact on kaolin markets within the study area. A Northern Ontario producer would have to compete with the long established southern U.S. producers, and would have a transportation disadvantage.

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CHAPTER 5.0: SILICA

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5.0 SILICA

5.1 Introduction and Overview

For this report silica includes material from natural sources such as silica sand, sandstone, quartzite, and quartz. Not included is secondary silica manufactured from natural sources; examples include fused silica, fumed silica, silica gel, and precipitated silica. Of these, only precipitated silica is used as a filler.

Natural silica is a commonly occurring mineral, but is not commonly found in deposits of high purity. Most silica comes from pits (silica sand and gravel) or quarries (sandstone, quartzite). It is seldom necessary to resort to expensive underground mining to obtain it.

Most silica deposits are mined to supply material for glass plants, foundries (mold sand), smelters (flux) or silica abrasive. Filler silica is usually a secondary product, representing small quantities but high-values.

To be suitable for fillers, natural silica almost always requires processing. In some cases washing and screening suffice, in other cases a more extensive process is required involving a combination of crushing, screening, magnetic separation, washing, desliming, acid leaching, froth flotation, drying and grinding operations.

Specifications vary for silica filler. In general, however filler buyers want a material with high brightness, high purity (usually 99.0% SiO_2 content or higher) and uniform size (often 325 mesh or finer).

The three largest users of silica filler are: the paint, rubber, and plastic industries. Together they account for over 97% of silica filler used in North America. Other uses include: putty, caulks and sealants, adhesives, wood fillers, and cleansers.

5.2 Production of Silica

5.2.1 Location of Producers

Silica is produced by over one hundred companies in the United States and Canada. Much of the production is used in the manufacture of glass and fiberglass, the preparation of foundry sand, the preparation of blasting sand, and as hydraulic fracturing sand. These uses do not have specifications as rigourous as those for fillers which require both high purity and fine, very uniform size. Thus most small silica producers do not produce significant quantities of filler-grade silica.

Presented in Table 5-1 is a list of prominent silica producers located within 800 kilometers of New Brunswick. The producers, in turn, are located on the map in Figure 5-1.

Within the market area of this study filler-grade silica comes from Quebec, Ontario (Indusmin), Pennsylvania, and Illinois (see Table 5-2).

Figure 5-1: Location map of prominent silica producers within 800 kilometers of New Brunswick.

	Company		Pits		
	Name	Location Head Office	Locations	Plant	Capacity (Use) Tonnes per Day
	New Brunswick				
1.	Chaleur Silica Ltd.	Petit Rocher	Bass River	Yes	150,000 t/a (grit, foundry, sandblast)
2.	Sussex Silica Inc.	Sussex	Cassidy Lake	Yes	500 (grit, pebbles, sand blast)
	Newfoundland				
3.	ERCO Industries Limited, (Dunville Mining Co.); a subsidiary of Tenneco Canada Inc.	Islington, Ontario	Villa Marie	Yes	1,360 (phosphorus production)
	Nova Scotia				
4.	Nova Scotia Sand & Gravel Ltd. (a subsidiary of L.E. Shaw Limited)	Lantz	Shubenacadie	Yes	1000 (general)
	Quebec				
5.	Armand Sicotte & Sons Ltd.	St. Hubert	Howick	No	1000 (chemicals, ferromanganese, cement)
6.	Baskatong Quartz Inc.	N/A	Charlevoix	Yes	1,360 (silicon, ferromanganese)
			Lac Bouchette	Yes	1,000 (silicon metal)

Table 5-1: Prominent silica producers within 800 kilometres of New Brunswick (Boucher 1987, U.S. Dept. of Mines 1986). See Location map - Figure 5-1.

	Company		Pits		
	Name	Location Head Office	Locations	Plant	Capacity (Use) Tonnes per Day
	Quebec				
7.	Elkem Metal Canada Inc.		Melocheville		
8.	Indusmin Ltd., (Quebec Silica Division)	Toronto	Saint-Canut	Yes	1,800 (various)
			Saint-Donat	Yes	1,080
9.	Industrie Loma Inc.	Beauport	Beauport	Yes	500
10.	La Compagnie Bon Sable Ltee		Ormstown	Yes	600 (foundries, fibreglass, glass, fill)
			St. Joseph-du-Lac		
11.	Melocheville Mining Limited	Montreal	Melocheville	1	1,000 (ferrosilican)
12.	Temisca Silica (1985) Inc.		Guigues Twp.		
	Ontario				
13.	Indusmin Ltd., (Ontario Silica Division)	Toronto	Badgeley Island	Yes	3,800
			Midland	Yes	1,200 (sand and flour for fillers)
14.	B-Mac Silicon Aggregates Ltd.	Bracebridge	Bracebridge	---	-------- (foundry, sandblast)
	Massachusetts				
15.	Holliston Sand Co., Inc.	Holliston	Middlesex	No	(sandblast)
16.	WHIBCO, Inc.	Leesburg, NJ	Plymouth	No	(sandblast)
	Rhode Island				
17.	Holliston Sand Co., Inc.	Slatersville	Providence	Yes	

TABLE 5-1 (continued)

Company		Pits		
Name	Location Head Office	Locations	Plant	Capacity (Use) Tonnes per Day
Connecticut				
18. The Feldspar Corp.	Spruce Pine, NC	Middlesex	Yes	(by-product)
19. Ottawa Silica Co., Connecticut Div.	Ottawa, IL	New London	Yes	
New York				
20. WHIBCO Inc.	Leesburg, NJ	Oneida	No	
		Saratoga	No	(moulding and foundry sand)
New Jersey				
21. Downer Silica Co.	N/A	Gloucester	N/A	*
22. George F. Pettinos, Inc.	Williamstown Junction	Cumberland	Yes	*
23. NJ Pulverizing Co.	Bayville	Ocean	Yes	*
24. NJ Silica Sand Co.	Millville	Cumberland	Yes	*
25. Owens-Illinois Inc.	Millville	Cumberland	No	*
26. Pennsylvania Glass Sand Corp.	Berkeley Springs, WV	Cumberland	Yes	*
27. South River Sand Co.	Old Bridge	Middlesex	Yes	*
28. The Marie Co., Inc.	Millville	Altantic,	N/A	*
		Camden,	N/A	*
		Cape May,	N/A	*
		Cumberland		*
29. Unimin Corp., Dividing Creek Plant	New Canaan, CT	Cumberland	No	*
30. U.S. Silica Co.	N/A	Cumberland	No	*
31. WHIBCO, Inc.	Leesburg, NJ	Cumberland	No	*

*The primary uses of silica sand produced in New Jersey are glass, moldings and cores for foundries, and sandblast sand.

TABLE 5-1 (continued)

Company		Pits		
Name	Location Head Office	Locations	Plant	Capacity (Use) Tonnes per Day
Pennsylvania				
32. Alliance Sand Co.	N/A	Carbon	N/A	
33. McCrady, Inc.	Pittsburgh	Allegheny	Yes	
34. U.S. Silica Co.	N/A	Huntingdon	N/A	(glass containers)

N/A Data not available

Table 5-1 (continued)

Producer	Grade	Use
U.S. Silica (a subsidiary of U.S. Borax)	Min-U-Sil 30	paint
Illinois Minerals (a subsidiary of Georgia Kaolin)	Imsil A-15 Imsil 1160 Imsil 1240	paint
Tamms Company	Bold Bond R Silver Bond B S - Micron Neosil XV	paint

Table 5-2: Producers of silica filler with typical grades and uses (Metal Economics Group, 1988)

5.2.2 Mining, Processing, and Beneficiating Technology

5.2.2.1 Mining

Silica sand is mined in a pit operation using bulldozers, backhoes, or front end loaders. Larger operations use clams or draglines. For poorly consolidated sandstones open pit operations are also used. Drill and blast techniques or tractor-mounted hydraulic hammers are usually required to break the rock.

Hard sandstones and quartzites are usually quarried using conventional bench methods with drilling and blasting. When the overburden is too thick, underground mining methods (horizontal adits, shallow declines, vertical shafts) are used. Underground mining is not common, however.

5.2.2.2 Processing and Beneficiation

The amount and type of raw material processing is

dependant upon the characteristics of the raw material and the specifications of the end use.

Silica sand in nature can contain many impurities. The impurities can be removed by several processes including washing, magnetic separation, and flotation. The last process is used to separate silica and clay. The sand is sorted/sized using screens or centrifuges. In some cases, the sand and pebbles are crushed and/or ground to produce fine material.

Sandstone must first be reduced to sand. Primary crushing is followed by autogenous crushing, hammer mills, or the use of secondary crushing plus rod or ball mills. Once crushed, the sandstone is purified. Washing, desliming, screening, and drying suffice for some sources; others require more intensive treatment including acid bleaching, magnetic separation, attrition scrubbing, and froth flotation. The cleaned material is then ready for grinding.

Quartzite is much harder than sandstone with the bonding material as strong as the quartz grains themselves. The size-reduction process therefore requires heavier crushers and more energy. Once crushed, quartzite is beneficiated in much the same manner as sandstone.

Quartz is rarely used as a filler source.

5.2.2.2.1 Grinding

Silica may be processed wet or dry (see Figure 5-2). The choice is dependent upon the types of impurities present, end use requirements, and environmental

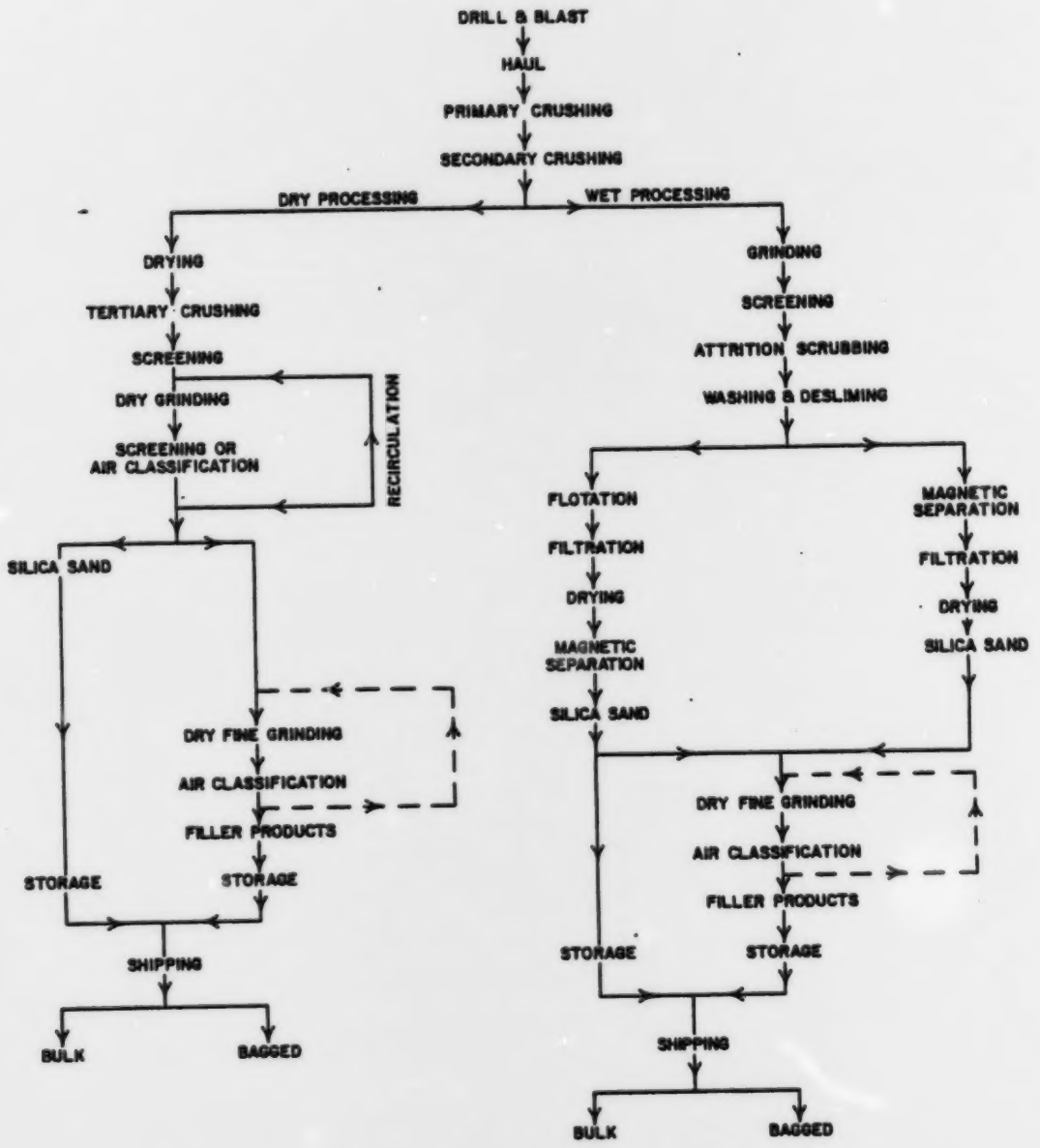


Figure 5-2: Dry or wet processing alternatives for silica (Guillet and Kriens 1984).

considerations. Concerns regarding silica dust (a cause of lung disorders) have made dry processing increasingly expensive. Wet processing, on the other hand, requires expensive drying.

Grinding is not suitable for some silica uses as it produces angular grains. For uses such as sand blasting, round grains such as those from screened sand are preferred.

Grinding of silica is difficult as the mineral is very hard and abrasive. To obtain fine grains for fillers ball or pebble mills are used. The grinding is followed by air classification where the oversize material is returned for regrinding. Common grades produced are 100 mesh, 200 mesh, and 325 mesh.

5.3 Utilization and Consumption

Silica fillers are used for a wide range of products. However it is estimated (Guillet and Kriens 1984) that three uses account for over 97% of the 77,000 tonnes of annual consumption:

paint	- 55,000 tonnes (71.5%)
plastics	- 15,000 tonnes (19.5%)
rubber	- 5,000 tonnes (6.5%)

Other uses account for the remaining 2,000 tonnes of annual consumption. These uses include: putty, caulks and sealants, adhesives (vinyl), wood fillers, asphaltic products (roofing, driveway compounds), buffing compounds (metal polishing), foundry mold washes (better cast surfaces), and household cleansers (scouring powders, hand soaps).

Another recent report (Metal Economics Group, 1988) reports a total United States consumption of silica flour at 125,000 tonnes with the largest use catagories being:

paint - 97,000 tonnes (78%)
plastics - 15,000 tonnes (12%)
rubber - 6,000 tonnes (5%)
adhesives and sealants - 6,000 tonnes (5%)

5.3.1 Paint Industry

5.3.1.1 Applications

In paint silica's primary function is to extend titanium dioxide, a primary pigment. In general, silica gives good scrubability, film toughness, and good weathering resistance. It also is used to flatten the gloss of paint. Specific uses include: exterior house paints, floor enamels, anti-rust paint (amorphous silica) block fillers (concrete) and traffic paints. These are specialty paints for which silica's benefits outweigh its high abrasiveness.

Paint silica comes from crystalline sources such as sandstone or quartzite and cryptocrystalline sources such as tripoli and novaculite.

Typical loadings in paint are 6 to 30 kilograms per 100 litres of paint. See section 2.3.1.1 for a background discussion on paint and the use of fillers in its manufacture.

5.3.1.2 Specifications

In the Canadian paint industry, the specifications shown in Table 5-3 are applied to silica. Grades used range from 325 mesh to 10 microns.

High brightness and low oil absorption are key properties in selecting a silica source.

5.3.1.3 Prices

In 1984, prices for paint-grade silica were quoted at $107 - $390 Cdn/tonne for 23 kg bags f.o.b. production site. The higher price was for 5 micron silica with 90-92 GE brightness. However, recent prices (see Table 5-4) are not as high.

5.3.1.4 Consumption Levels

A "typical" interior paint contains 1.5% silica by weight. North American silica consumption by paint manufacturers is 55,000 tonnes (1980 - 1985 data). In Canada consumption in 1983 was estimated at 567 tonnes (lump), 111 tonnes (sand), and 3,118 tonnes (flour or filler). By province the silica filler consumption was:

Newfoundland	quantity withheld, 1 paint plant
Nova Scotia	quantity withheld, 1 paint plant
New Brunswick	no paint plants in 1983, 1 in 1988
Quebec	1054 tonnes in 10 paint plants
Ontario	592 tonnes in 22 paint plants
Manitoba	0 tonnes in 3 paint plants
Alberta	0 tonnes in 1 paint plant
British Columbia	1,427 tonnes in 3 paint plants

Chemical Analysis

SiO_2	=	97.5 - 99.7%
Al_2O_3	=	0.06 - 0.18%
Fe_2O_3	=	0.01 - 0.02%
TiO_2	=	0.02%
CaO	=	0.02 - 0.1%
MgO	=	0.01%

Physical specifications

moisture content	=	0.25 - 0.5%
hardness (Moh's scale)	=	6.5 - 7.0
specific gravity (g/cm^3)	=	2.65
bulking factor (gals/lb)	=	0.0453
pH	=	6.1 - 7.3
oil absorption ($cm^3/100g$)	=	22.0 - 30.0
refractive index	=	1.45 - 1.54

Table 5-3: **Specifications for silica fillers in the Canadian paint industry (Prud'homme and Francis 1987a).**

DESCRIPTION			PRICE ($Cdn/tonne)*
Silica	-	Amorphous, dry-ground bags by carload, 93% 200 mesh f.o.b. works	$42.60 - $44.70
	-	same as above except 98% 200 mesh	44.00 - 46.10
	-	same as above except 93% 325 mesh	47.40 - 48.80
	-	same as above except 97% 325 mesh	47.40 - 48.80
	-	same as above except 98.5% 325 mesh	50.90
	-	same as above except 99.5% 325 mesh	70.80 - 74.90
Silica	-	dry-ground, bags by carload f.o.b. works, 99.9% 400 mesh micronized	99.0 - 104.00
	-	same as above except 99% under 15 microns, micronize	109.00 - 113.00
	-	same as above except 99% under 10 microns, micronized	143.00 - 144.00
Silica	-	hard-quartz, 99.5% SiO_2 325 mesh, bags by carload f.o.b. works	50.90
	-	same as above except 140 mesh	47.80

$1 Cdn = $0.80 U.S.

Table 5-4: **Prices for filler-grade silica, September 1988 (Chemical Marketing Reporter, 1988)**

Detailed figures for United States consumption are not available, however consumption in the northeastern United States (i.e. Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, Pennsylvania and New Jersey) for all silica fillers was 19,000 tonnes in 1985. Estimates are available in section 3.3.4.4 (Tepordei, 1986).

The largest single use of silica in paint is probably Glidden Coatings and Resins at about 6,300 tonnes per year.

Based upon a 1984 study it is estimated that 35,000 tonnes of silica filler is used annually in the market area (Guillet and Kriens, 1984).

5.3.2 Rubber

5.3.2.1 Applications

Ground silica filler is used in the production of rubber belts and hoses (Prud'homme and Francis 1987a). As well, it is used to extend silicone rubber usually in the form of fumed silica. In this use its low oil absorption, easy dispersibility and silicone-compatibility are valuable properties; however its key benefit is to lower product cost (Guillet and Kriens 1984). See Section 2.3.3.1 for a background discussion of the use of fillers in rubber products.

5.3.2.2 Specifications

Rubber silica must have high brightness. Size must be fine, in the range of 10 to 30 microns.

5.3.2.3 Prices

In 1984 rubber silica was quoted at $170 - 390 Cdn/tonne (Guillet and Kriens 1984). However more recent prices are considerably lower (See Table 5-4).

5.3.2.4 Consumption Levels

There is little available data on the quantity of fillers consumed in the rubber industry in the study area (see discussion Section 3.3.7.4). A typical rubber compound contains about 30% loading or filling pigments (carbon black, calcium carbonate, silica, zinc oxide, crushed coal, barite, and clays) (Austin 1984). The mix of fillers used in production is unknown as it varies from product to product.

Figures are available for total Canadian silica production and imports for all uses (Prud'homme and Francis 1987c).

	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.
Year	'85	'85	'85	'85	'85	'85
tonnes utilized						
-domestic production	W	0	W	W	738,000	1,013,000
-imports*	0	0	25	11	9,262	114,229
number of rubber plants	0	0	4	0	36	79

*not including foundry and glass sand

Information on the rubber industry in the northeastern United States is presented in Table 3-15. A total of 21,000 tonnes of silica filler was consumed for all uses in North American in 1985 (Tepordei 1986).

Based upon a 1984 study it is estimated that 3,000 tonnes of silica a year is consumed by the rubber industry in the market area (Canada and United States) (Guillet and Kriens, 1984). Another study estimated consumption at 6,000 tonnes per year (Metal Economics Group, 1988).

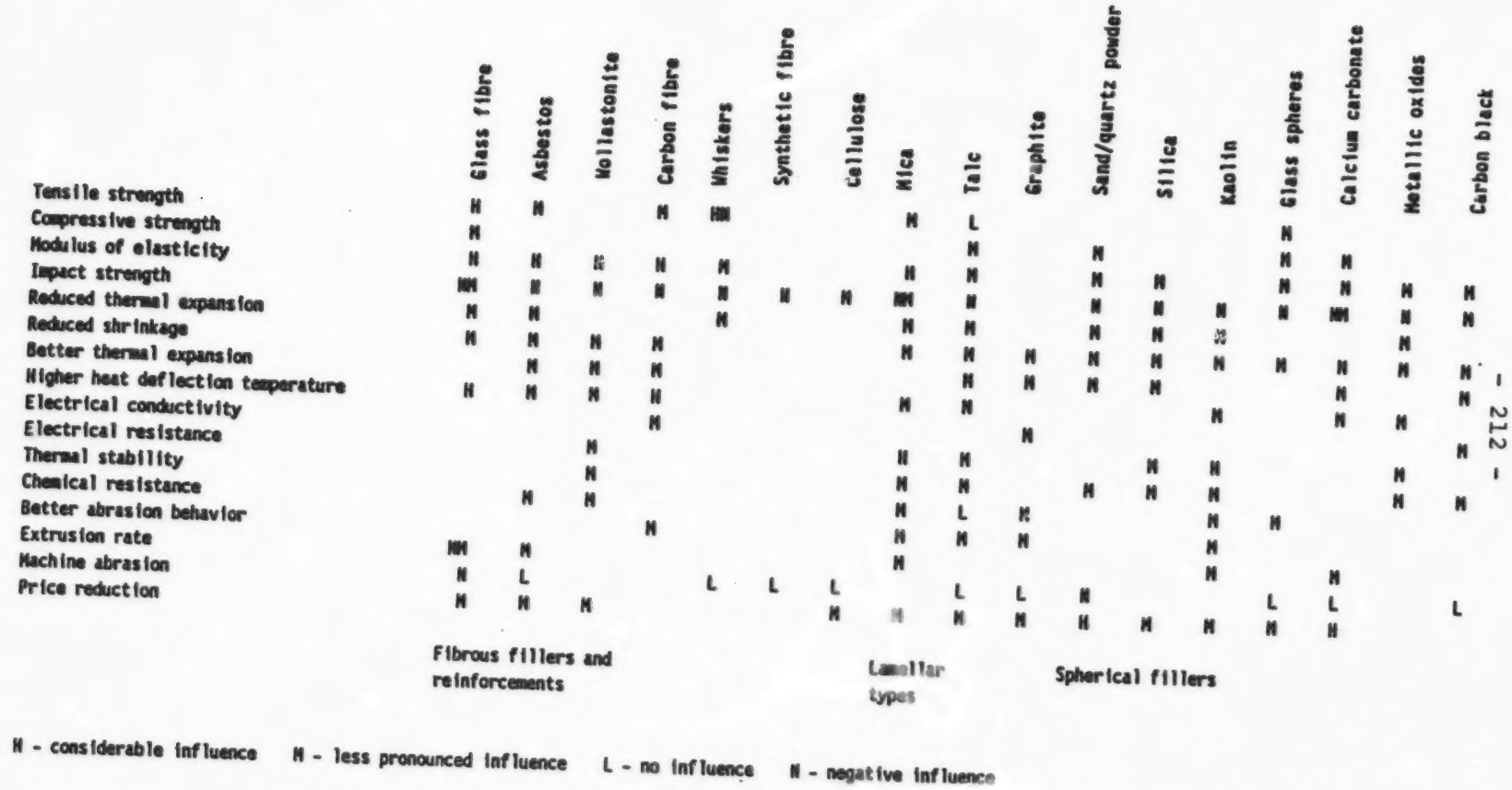
5.3.3 Plastic Industry

5.3.3.1 Applications

Silica filler is used with the following types of plastics:

- phenolics
- polyvinyl chlorides
- polyesters (unsaturated)
- polyethlenes
- epoxies
- polyurethates
- nylons

Silica provides good dielectric properties as well as inertness and low oil absorption to plastics. Silica also improves compressive strength, flexural strength and dimensional stability. Sometimes crytocrystalline silica is treated with silanes or titanite coupling agents to improve its performance in plastics. Table 5-5, 5-6 and 5-7 provides a comparison of the effects of silica and other fillers upon thermoplastics, low density polyethylene, and filled rigid PVC respectively. See Section 2.3.2.1 for a background discussion of the use of fillers in plastic production.



H - considerable influence M - less pronounced influence L - no influence N - negative influence

Table 5-5: Diagramatic presentation of the influence of fillers and reinforcements on thermoplastics (Gachter and Muller, 1985)

Material	Filler Content elasticity (% by wt.)	Tensile Strength (N/mm^2)	Elongation (%)	Modulus of (N/mm^2)	Melt Index 190/5 (g/10 min)	Heat Deflection Temperature (ISO/R75A. 1.85 N/mm^2) (^oC)	Ball indentation hardness (N/mm^2)	Density (g/cm^3)
Low density polyethylene	--	10	500	210	1.7	35	16	0.92
Chalk	40	16	220	900	0.2	--	--	1.26
Glass fiber	30	24	65	1200	1.6	--	33	1.11
Asbestos	30	20	20	670	2.3	--	22	1.13
Talc	30	16	40	600	1.1	--	30	1.14
Mica	30	13	46	440	1.2	--	27	1.16
Glass spheres < 50 um	30	10	73	290	2.6	--	19	1.11
Quartz powder	30	12	77	400	2.5	--	23	1.14

Table 5-6: Influence of fillers on the properties of low-density polyethylene (Gachter and Muller 1985)

Material	Filler Content (pts. by wt)	Tensile Strength (N/mm^2)	Elongation at Break (%)	Modulus of elasticity (N/mm^2)	Vicat Softening Point (°C)	Notched Impact strength (Charpy) 23°C (mJ/mm^2)	Density (g/cm^3)
S-PVC unplasticized	--	60	6 to 10	2700	85	3	1.36
Calcium carbonate, natural	30 to 100	46	8	3200	94 to 116	9	1.53 to 1.78
Calcium carbonate, precipitated	15	30 to 47	6	3100	87	14	1.45
Talc	20	34	6	3500	--	--	1.48
Quartz powder	20	38	--	3100	--	--	--
Glass fiber	40	25	3	8000	85	--	--
Asbestos	30	33	1.2	5500	85	--	1.65
Wollastonite	20	25	5.4	--	--	3	1.47

Table 5-7: Properties of filled rigid PVC (Gachter and Muller 1985)

5.3.3.2 **Specifications**

In general, filler selection is dependent upon:

a) particle size, in particular the match of the particle size distribution curve to the resin,

b) possible catalytic activities at the filler surface,

c) dispersibility,

d) linkage with plastic matrix,

e) abrasiveness on processing machines,

f) properties of resultant compound,

g) environmental and public health concerns, and

h) cost

Silica is a low-cost filler. Both natural and crytocrystalline silicas are acceptable. Coated and uncoated silicas are used, the coating aids silica dispersion and bonding with plastic. Silicas should have high brightness. Grain size should be in the range of 45 microns (325 mesh) to 5 microns.

5.3.3.3 **Prices**

Prices of $190-400 Cdn/tonne for uncoated silica and $200-530 Cdn/tonne for coated silica were quoted in 1984 (packed in 23 kg bags, f.o.b. production site). Recent

prices seem to be considerably lower (see Table 5-4).

5.3.3.4 Consumption Levels

In 1983, the following information was available for total silica production and imports for all uses (Prud'homme and Francis 1987c).

	NFLD.	P.E.I.	N.S.	N.B.	QUE.	ONT.
Year	'85	'85	'85	'85	'85	'85
tonnes utilized						
-domestic production	W	0	W	W	738,000	1,013,000
-imports*	0	0	25	11	9,262	114,229
number of rubber plants	0	0	4	0	36	79

*not including foundry and glass sand

Estimates regarding plastics production in the portion of the United States within the study area are presented in Section 3.3.3.4.

Total silica filler consumption for all uses including plastics in the northeastern United States was 21,000 tonnes in 1985 (Tepordei 1986), while for the entire United States, estimated filler consumption for plastics only was:

1,100,000 tonnes in 1980
1,780,000 tonnes in 1985
2,900,000 tonnes (projected) in 1990

Based upon a 1984 study, it is estimated that 10,000 tonnes of silica is consumed annually in the total market area of this study (Canada and United States) (Guillet and Kriens 1984).

5.4 Competitive Materials

Calcium carbonate competes with silica as a low cost filler for paints. The oil absorption properties of the two minerals are similar but calcium carbonate has lower abrasion. In some applications such as interior floor paints or porch paints, silica is preferred because of its greater scrubability due to its superior durability and inertness.

Calcined kaolin competes with silica for use in traffic paints. The kaolin is more costly and less durable, however (Guillet and Kriens, 1984).

5.5 Trends and Market Potential

Paints. Silica use in paints is forecast for slow growth (Guillet and Kriens, 1984).

Plastics. Silica consumption in the plastics industry is expected to grow rapidly (Guillet and Kriens, 1984).

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CHAPTER 6.0: TRANSPORTATION AND PACKAGING

6.0 TRANSPORTATION AND PACKAGING

Mineral fillers may be shipped in different physical forms (bagged, bulk, or slurry) and by different transport modes (road, rail, or water). Each different form or mode imposes different costs on the shipper.

Filler in slurry form is desirable for both the producer and the consumer: the producer eliminates the extra costs associated with drying and handling, while the consumer receives a uniform product less likely to be contaminated. However, this is also the most difficult form to transport, since it requires special handling for both loading and unloading, and tank trucks or rail tank cars for the actual movements. The cost of transporting filler in slurry form, therefore, will vary with the availability and other demand for the necessary specialized equipment, in addition to the quantity of the material and the distance to be moved. Actual freight rates by rail or truck have to be determined by negotiation.

Bagged filler is the most versatile physical form, from a transportation perspective: the filler may be moved by road, rail, or ship; is easily transferred from one haulage system to another; and is less vulnerable to contamination. However, it also requires the most handling, imposes additional bag costs and other costs due to bag losses, breakage and spillage, and is generally the most expensive form for shipment.

Bulk filler may also be moved by road, rail, or ship, and can be transferred from one haulage system to another. It is the least expensive form for shipment since it

requires the least handling, but it is also the form most subject to contamination. This disadvantage is minimized by using truck or covered rail cars. Movement by rail and ship may be justified when relatively large quantities are needed by the consumer. However, for smaller loads, trucking may be preferred, since the greater speed and frequency of delivery by truck reduces the need for warehousing and storage by the consumer, thus reducing inventory costs.

Trucking cost comparisons of the four minerals under review are presented in Table 6-1. The costs were estimated using the Transport Canada Truck Operating Cost Model (1986) developed by Trimac Consulting Services Ltd. The costs were estimated for a six-axle tractor semi-trailer carrying the minerals in bulk form with no backhauls. The following points may be noted:

1. The costs presented are distance-based. However, actual point to point freight rates may be determined by negotiation between the consumer and the carrier (if the contract for the supply of the mineral is f.o.b.) or between the producer and the carrier, and will take into account other factors such as the level of consumption, the possibility of backhauls, whether the contract is long-term or short-term, the competitive threat from other carriers and modes, etc.

2. Shipments across international borders are higher than the estimates presented, due to additional costs imposed by differences in trucking laws, licences and fees, etc.

3. For hauls longer than 500 km, or for markets too far away to be serviced within a 24 hour time frame, the lower unit cost of rail may make rail shipments on the whole less expensive than truck, in spite of its higher inventory costs. The shipper/receiver will have to balance the lower cost of rail against its service delays caused by switching problems, marshalling yard congestion, etc., in determining the most appropriate mode for a specific shipment. Piggyback alternatives to straight rail shipments may also become more attractive in spite of the greater handling costs imposed by switching between modes.

4. In terms of trucking costs, a barite mine located in central New Brunswick would have a clear cost advantage over mines in Matawatchan, PQ and Cartersville, GA in serving a paint plant located in Richibucto, New Brunswick. But it has a substantial cost disadvantage against the Matawatchan mine in serving plants in Montreal and Toronto. It may also be noted that, if the current demand for barite by the Richibucto plant is large enough that existing suppliers ship in the mineral by rail, the current shipping cost by rail from these suppliers may be competitive with a trucking shipment from central New Brunswick.

5. In terms of trucking costs, a silica mine located in Sussex, New Brunswick would have a cost advantage over existing suppliers only for a paint plant located in Richibucto, New Brunswick. Plants in Saint Canut, Quebec and Midland, Ontario have substantial trucking cost advantages over a

Sussex mine in supplying plants in Montreal and Toronto, respectively. Again, it should be pointed out that, if the demand for silica by the Richibucto plant is so large that current suppliers ship in the filler by rail, then current rail shipping costs from these suppliers could be competitive with trucking costs from Sussex, New Brunswick.

6. In terms of trucking costs, a calcium carbonate operation located in Havelock, New Brunswick would have a substantial cost advantage over a similar operation in North Adams, MA, in supplying a pulp and paper mill in Newcastle, New Brunswick.

In summary, the costs presented are for comparison purposes only. Actual haulage rates can only be determined by negotiation for specific minerals in specific physical forms between specific origins and destinations in specific quantities by specific modes.

Origin	Destination	Distance (km)	Volume (Tonnes)	Cost ($)
	BARITE			
Matawatchan, ON	Montreal, PQ	393	26.58	1,926.13
Matawatchan, ON	Toronto, ON	322	26.58	628.84
Matawatchan, ON	Richibucto, NB	1008	26.58	1,926.13
Cartersville, GA	Montreal, PQ	1753	26.58	3,269.60
Cartersville, GA	Toronto, ON	1797	26.58	3,346.81
Cartersville, GA	Richibucto, NB	2761	26.58	4,978.95
Doaktown, NB	Montreal, PQ	916	26.58	1,755.50
Doaktown, NB	Toronto, ON	1459	26.58	2,747.55
Doaktown, NB	Richibucto, NB	155	26.58	304.72
	SILICA			
Mapleton, PA	Montreal, PQ	974	26.58	1,863.19
Mapleton PA	Toronto, ON	1341	26.58	2,535.05
Mapleton, PA	Richibucto, NB	1982	26.58	3,668.87
Midland, ON	Montreal, PQ	720	26.58	1,388.52
Midland, ON	Toronto, ON	171	26.58	335.53
Midland, ON	Richibucto, NB	1728	26.58	3,225.62
Sussex, NB	Montreal, PQ	944	26.58	1,807.54
Sussex, NB	Toronto, ON	1487	26.58	2,797.73
Sussex, NB	Richibucto, NB	166	26.58	325.77
Saint Canut, PQ	Montreal, PQ	35	26.58	73.74
Saint Canut, PQ	Toronto, ON	584	26.58	1,131.12
Saint Canut, PQ	Richibucto, NB	1043	26.58	1,990.77
	KAOLIN			
McIntyre, GA	Newcastle, NB	2649	17.25	4,693.86
Langley, SC	Newcastle, NB	2346	17.25	4,199.64
	CARBONATE			
North Adams, MA	Newcastle, NB	1300	26.58	2,460.81
Havelock, NB	Newcastle, NB	160	26.58	314.06

Table 6-1: Estimated transport costs of minerals by truck between specific origins and destinations.

CHAPTER 7.0: SUMMARY OF MARKETS AND DEVELOPMENT POTENTIAL

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7.0 SUMMARY OF MARKETS AND DEVELOPMENT POTENTIAL

An overall evaluation of the market potential for the filler minerals included in the study must encompass an extensive range of parameters. Certain factors such as existing production capacity, established consumption trends, and the interaction between these market forces are, to a large degree, quantifiable and have a direct impact on the assessment of the market potential. Indirect factors such as global economic trends, free trade between Canada and the United States, and similar variables are much more difficult to assess in a concrete manner. However, the impact of these indirect factors may well have a greater influence on the market potential for mineral fillers produced in New Brunswick than many of the direct market influences. However, the present evaluation will concentrate primarily on the factors of direct relevance to the level of filler consumption and will make only general reference to the more indirect factors.

The major market sectors for the mineral filler commodities included in the study are the plastic, paint, paper and rubber industries (Table 7-1). Canada is generally regarded as consuming 7 to 10% of the quantity of mineral fillers consumed in the United States. Tables 7-2 and 7-3 indicate the relative consumption of various fillers in the two countries and the import - export relationships between them.

The organizational structure of the report has allocated an individual chapter to each mineral filler commodity. Within these chapters, consumption is discussed for various industries in the specific context of the individual mineral filler. This section will reverse this

Minerals	Paper	Paint	Plastics	Rubber	Other	Total
Kaolin	3,430	200	90	350	160	4,230
Calcium carbonate	300	330	400	120	1,100	2,250
Talc	90	170	60	40	80	440
Silica	15	90	20	50	10	185
Alumina hydrate	20	a	80	5	50	155
Mica	a	25	10	5	70	110
All other	25	135	40	5	25	230
Total	3,880	950	700	575	1,495	7,600

a - Minor

Table 7-1: **Estimated North American consumption of extender and filler minerals in 1983 ('000's tons) (Eckert 1984).**

Mineral	U.S.A.	Canada	Total
Kaolin	3,980	250	4,230
Calcium carbonate	2,100	150	2,250
Talc	405	35	440
Silica	165	20	185
Alumina hydrate	150	5	155
Mica	100	10	110
All other	200	30	230
Total	7,100	500	7,600

Table 7-2: **Estimated North American consumption of extender and filler minerals by country in 1983 ('000's tons) Eckert 1984).**

Mineral	From USA to Canada	From Canada to USA
Kaolin	200	--
Calcium carbonate	50	25
Talc	25	10
Silica	10	--
Alumina hydrate	3	2
Mica	2	5
All other	30	25
Total	320	67

Table 7-3: Exports of industrial minerals in 1983 ('000's tons) (Eckert 1984).

approach and assess the main consuming industries on an individual basis.

7.1 Paint Industry

Mineral fillers are used in the paint industry to reduce the quantities of prime pigment that are required and thus reduce the cost of the manufactured product. On a quantity-consumed basis, carbonate and kaolin fillers represent a major share of the market. However, the paint industry represents 60 to 80 of the consumption of barite and silica fillers.

The compatibility of carbonate fillers with water-based paints is a significant factor in its high market share. Projected increases in the use of this type of paint due to tighter environmental controls on the manufacture and use of oil-based paints suggests the market share could increase.

The use of calcium carbonate fillers in the paint industry is largely a function of cost relative to other products. In particular, the cost cycles of prime pigments like titanium dioxide have a significant influence on calcium carbonate filler consumption. As titanium dioxide increases in cost, there is a tendency to reduce the quantity used by increasing the calcium carbonate filler level. The increased availability of ultrafine calcium carbonate products and the use of wet or dry slurries in the transport of the product are positive factors for paint manufacturers and could contribute to an increased market share for carbonate fillers. However, these ultrafine products are essentially adapted paper grades and represent only about 10,000 tonnes of the current United States market in paint (Dickson, 1987).

Kaolin also is used in water based paints. In particular, water washed kaolin is used to enhance the visocity of the paint. Increases in the use of water-based paints would presumably result in increased kaolin consumption.

Silica is used in a variety of paint types to flatten or reduce the gloss of the paint. In addition, one of its primary applications is in the manufacture of traffic line (highway) paint where it imparts abrasion resistance, and hence durability, to the paint. Such specialized uses suggest the market for silica filler in the paint industry to be reasonably stable.

Barite is also used in certain specialized paint applications particularly in the automotive industry. However, calcium carbonate is a competing product in some applications and cost is a critical factor in the selection.

Within the paint industry, there are a number of factors which may have considerable influence on the market potential for filler materials. The Canada - United States Free Trade Agreement will result in a phase-out of a 9% Canadian import duty on paint. However, the transportation costs associated with paint's high per-unit weight tends to discourage long-distance shipments. Aggressive marketing by large producers to increase their market share is creating difficulties for small producers. However, small producers often occupy specialized niches. In addition, high transportation costs favour small regional producers.

In Canada, the value of paint sales has increased by an average of 17% per year since 1982. However, this reflects price gains more than volume increases. Profit margins have been small, averaging 3.8% of sales in Canada and 2.9% in the United States (The Financial Post; December 5, 1988). In the United States the value of paint sales grew by about 5.6% in 1987. A similar growth is expected in 1988 (United States Department of Commerce, 1988). Longer term projections are dependant on the demand for specialty coatings, competitive pressure from substitute materials such as vinyl siding, and environmental concerns. In general, paint sales tend to follow the business cycle, particularly in the automotive and new construction sectors. Trade sales (domestic users and house-paint contractors) tend to represent a more stable market. Overall the paint industry is regarded as a mature industry with limited potential for overall market expansion.

Based on this background, a New Brunswick-based producer of mineral fillers would have to contend with a mature marketplace with established business relationships between suppliers and consumers. Four paint producers are

located in the Atlantic Provinces and would be regarded as the highest potential for market penetration due to transportation advantages. However, an overall evaluation suggests that the paint industry has a relatively low market potential for mineral fillers produced in New Brunswick.

7.2 Plastic Industry

Consumption of mineral fillers in the plastic industry traditionally has been as an extender for more expensive resins. More recently, improvement of the performance properties of the manufactured product has been an important factor in the use of fillers. Carbonate fillers represent over half the quantities consumed. Kaolin represents 10 to 15% with barite and silica representing small amounts. However, the plastic industry represents about 25% of the market for barite fillers.

Modification of plastics to improve performance or reduce costs can be accomplished by: producing an alloy of two different resins; reinforcing with fibrous materials; or by compounding with minerals. Over 20 different resins can be compounded with fillers but four (polyvinyl chloride (PVC), polyester, polypropylene, and nylon) account for 90% of the demand.

The rate of growth of the plastic industry has slowed in the past decade. The production of the four main filler-consuming resins has increased at a rate of 8% annually in the period 1967 to 1985 but only at a rate of 4% for the 1977 to 1985 period. However, the use of mineral fillers increased at a rate of 19% per year in the 1977 to 1985 period. Overall consumption of mineral fillers by the plastics industry is in the order of 1 million tonnes per

year. (Haskin and Eckert, 1987).

Calcium carbonate fillers are used in plastics primarily as a resin extender. Most of the consumption is for polyvinyl chloride (PVC) and polyester. Research on methods to increase filler loading levels suggests the potential for increased consumption of carbonate fillers in the plastics industry. Finer particle sizes, modified particle size distributions, and surface treatments of particles are all components which could contribute to consumption increases. Development of an appropriate coupling agent to improve the bonding between the resin and the filler would also have important implications. Traditionally calcium carbonate has been regarded as a cheap bulk filler in the plastics industry but now must be able to impart useful properties to the final product to compete against other filler materials.

Applications of PVC include pipes, house siding and similar construction products. Development of new types of "weatherable" vinyl siding could increase the consumption of carbonate fillers. However, the potential for market growth in this sector is closely related to construction activity and the overall state of the economy.

The automotive industry represents a market with a large potential for growth. Polyester resins reinforced by fiberglass and filled with calcium carbonate are used in several applications within automobiles. The increased use of plastic body panels in cars would represent a large increase in the quantities of plastic, and hence filler, that are used. The Pontiac Fiero was the first model to have such panels. General Motors originally anticipated producing other similarly equipped models by the late 1980's

but the plans were delayed. Growth of this market sector could be erratic in the short term but considerable growth in the long term is expected (Dickson 1987).

Kaolin is also used as a resin extender in plastics. Water washed kaolin is used in thermoset plastics such as polyester and phenolics. Calcined kaolin is used in polyvinyl chloride wire and cable coatings. Surface treated kaolin is used in nylon and other applications. Surface treated kaolins have improved dispersion properties and are becoming increasingly popular in various plastics applications.

Barite is used in plastics as a reinforcing agent and to improve dimensional stability. Typical products include polyvinyl chlorides, polyesters, and polyurethane in manufactured goods such as floor coverings, furniture, and automotive parts. Barite is also used for radiation shielding as it absorbs gamma rays and x-rays. Silica fillers are used in a wide range of plastic products to provide good dielectric properties and increase strength.

The diversity of the plastics industry and the wide variety of manufactured products which result make the assessment of market trends a complex task. Technological advances have been a factor in the increased level of consumption. However, the substitution of plastics for a wide variety of commonplace products is estimated to have accounted for over one-half the growth in mineral consumption in plastics over the past 10 years. The automotive industry, appliance manufacture, and electronic parts production all contributed to this trend. In general consumption of plastic is expected to increase at 5 to 7% per year in the 1985 to 1990 period. Consumption of mineral

fillers will exceed this rate and increase at 8 to 10% per year. Nylon (16%) and polypropylene (11%) will have the most rapid rates of increase in the consumption of fillers (Haskin and Eckert, 1987).

In the context of a producer of mineral fillers situated in New Brunswick there are several plastic producers located in the Atlantic region. However, the industry is concentrated in the Great Lakes and eastern United States regions (southern Ontario, Montreal, Massachusetts, New Jersey, Pennsylvania, and New York). The distances to these markets and diversity of the marketplace would be negative factors. The diversity could be considered an advantage if specialized products for certain market niches could be produced but such markets would probably have low levels of consumption. The overall growth potential of the market must also be regarded as a positive factor.

The plastics industry is regarded as having moderate potential for a producer of mineral fillers located in New Brunswick. Such a producer would have to compete against established producers with a geographic transportation advantage relative to the major components of the market.

7.3 Paper Industry

The paper industry represents nearly half the total North American consumption of mineral fillers and accounts for over 80% of the kaolin filler consumption. The paper industry also represents 5 to 10% of the ground carbonate filler market and 65 to 90% of the precipitated calcium carbonate market. As fillers, these minerals are used to reduce costs by displacing more expensive wood fibers and to

impart certain physical properties. As coatings, they enhance gloss, opacity, brightness and ink receptivity.

High quality papers have high loading levels of fillers. Less expensive grades such as tissue or packaging board contain little or no filler material. Loading levels in newsprint are in the 0 to 10% range with 3 to 5% regarded as typical. Kaolin accounts for over 80% of the fillers and 90% of the coatings used in the North American paper industry. Kaolin is compatible with the acid sizing processing used by much of the paper industry and this accounts for it being the material of choice for a large segment of the industry.

Calcium carbonate is second to kaolin as a filler and third, after kaolin and titanium dioxide as coating. Precipitated calcium carbonate has been the preferred form of carbonate in the paper industry. However, shortages of supply in the 1970's permitted producers of ground carbonate to gain some market share. Improved grinding technology, i.e., the ability to obtain finer grades, may also have been a factor. Carbonate fillers can be used as a filler only in papers manufactured by the alkaline or basic sizing process. Thus carbonate fillers are consumed as a filler by only a small, but growing segment of the paper industry. The paper-making process is not a factor in the use of carbonate as a coating material.

The gradual conversion of paper mills from the acid sizing process to alkaline or neutral sizing will have an impact on the substitution of carbonate fillers for kaolin. The conversion trend is likely to continue due to the reduction in paper production costs which result. Acceptance of paper produced by alkaline sizing is gradually

increasing and could be a factor in accelerating the conversion trend. Increased demand for coated paper could also result in a greater use of filler materials. Carbonate fillers have a cost advantage relative to kaolin but the established use of kaolin and improved methods of kaolin beneficiation are factors. The use of other commodities such as talc or titanium dioxide are also factors.

The growth in the use of electronic communication media (e.g., television, on-line data services, etc.) has been a factor in reduced sales of magazines, a major user of coated papers. However, continued growth of the paper industry is still anticipated. Combined shipments by the paper and allied products sectors were expected to rise 2.6 in 1988 over record 1987 levels (after adjustment for inflation) (United States Department of Commerce 1988). Coated and glazed paper product shipments are forecast to increase 3.5% a year during the 1988 to 1992 period. These statistics suggest the paper industry to be a continuing growth market.

In the context of a New Brunswick producer of mineral fillers, the paper industry must be regarded as a high priority market. In addition to production in New Brunswick (7 mills) and Nova Scotia (3 mills), the State of Maine has 18 mills and accounts for 13.9% of the total paper tonnage produced in the United States. The presence of such a significant market for either carbonate or kaolin filler within relatively short transportation distances is a positive factor.

7.4 Rubber Industry

The function of fillers in rubber products is primarily to dilute the rubber content and thus reduce costs. Statistics on the consumption levels for the industry vary, largely due to varying definitions of what is included in the industry. Kaolin and carbonate fillers have substantial market shares. Carpet backing is occasionally included with the rubber industry and consumes large quantities of fillers, largely calcium carbonate but also barite and other fillers.

The rubber industry in the study area is concentrated in southern Ontario and Ohio and is not considered a high priority market due to the distances involved. The one manufacturer of carpet backing in Atlantic Canada consumes about 1,600 tonnes of calcium carbonate annually. The demand for synthetic rubber is projected to have a small growth of 0.6% in 1988 and little or no growth in the 1988 to 1992 period. (United States Department of Commerce 1988). General purpose rubber (such as tires) dominates the market and is a major factor in determining the trend. Demand for specialty rubber is expected to have substantial growth in many sectors such as those suitable for high temperature applications.

7.5 Other Markets

The putty, caulk and sealant industry consumes significant quantities of fillers. Carbonate fillers have a large market share. Adhesives are commonly included in the same general category as sealants. The function of the filler is to reduce the quantity of polymer resin required. A filler to binder ratio of 10 or 12 to 1 is common.

Putties can contain up to 86% filler and some high performance sealants contain 25 to 40% filler. One of the major growth markets in the adhesives sector is for ready-mixed tiling cements. Joint compounds for the construction industry consumes large quantities of carbonate fillers.

Due to the nature of these products and their affiliation with building construction, both the consumption and manufacture of these products tends to be centred in proximity to large population concentrations. The total market for adhesive products in the United States has been estimated at 1,600,000 tonnes per year and is growing at a rate of 5% per year. Caulk and sealants represent a smaller market but also is experiencing growth. Adhesives used in the packaging material market are expected to double in demand over the next decade. The packaging industry has the largest dollar value of the adhesives and sealant market with the construction industry second. However, the construction industry consumes a larger quantity (about 1 to 2 million tonnes) mainly in the manufacture of wood products such as plywood (O'Driscoll, 1988).

The automobile industry represents a potential growth market for adhesives. They are already used extensively, e.g., door seals, etc., but on-going research suggests adhesives could replace, or reduce the number of spot welds.

7.6 Implications for a New Brunswick Based Development

7.6.1 Barite

The overall market for barite filler in the study area is relatively small. The paint industry is typically the largest consumer. There is currently no production of

barite in the Province and only limited definition of the resource. In view of the relatively high quality of material required for filler use and the relatively low market potential, it is questionable if a production operation could be supported solely to supply the filler market. It would appear more probable that an operation would be initiated to supply non-filler markets such as the drilling mud industry. Filler production could then be considered as a component of overall production. Based on such a scenario, it would appear that the potential for a development would be to some extent dependant on the future prospects for oil and gas exploration off the east coast of Canada. An extensive exploration program would require substantial amounts of drilling mud and create a demand for barite. Since such a program is not presently anticipated, it is not likely that development of the capability to supply filler grade barite will be achieved in the foreseeable future.

7.6.2 Carbonate

The production of carbonate materials is well established at several locations in the Province but none of the operations currently produce a fine enough product to service most filler consumers. However, the paper industry represents a significant potential market within relatively short transportation distances. Much of this potential market has limitations with regard to the use of calcium carbonate. Few operations have converted from the acid sizing process and hence would use kaolin rather than carbonate. Futhermore many of the operations produce newsprint which requires little or no filler material. Nevertheless, a New Brunswick producer would have a transportation advantage for much of the market area. As

the conversion to alkaline or neutral sizing progresses the market for carbonate filler would continue to grow.

The potential for substantially increased levels of consumption of calcium carbonate fillers in the plastic industry, particularly plastic autobody parts, is also a significant factor in the overall market. The positive outlook for calcium carbonate fillers has been a factor in several recent expansions, as well as some takeovers within the industry. As an example of this, Steep Rock Resources of Perth, Ontario has recently (1987) expanded its capacity by 45,000 tonnes per year. The increased production of calcium carbonate is in a slurry form and is directed primarily at the paper industry. Steep Rock was formerly a subsidiary of Canadian Pacific Ltd. The expanded operation (known as Ontario Carbonate) was a joint venture with Combustion Engineering's subsidiary Georgia Kaolin Co. (a major supplier of filler and coating kaolins to the paper industry). In 1988 MAS Minerals Corp. (a subsidiary of a leading European filler producer, Pluess-Staufer AG of Switzerland) acquired 90.5% of the shares of Steep Rock Resources. Much of the recent activity was based on projected increases in carbonate filler consumption in plastics for the automobile industry as well as in the paper industry. However, the market has not, as yet, increased to the projected quantities. This has lead to a considerable over-capacity within the industry.

Most of the added capacity has been in fine ground carbonate products or in precipitated calcium carbonate (PCC). Satellite (or "portable") PCC plants have lead to increased consumption in the paper industry. However, in many cases, these satellite plants tend to be distant from competing supplies of fine ground calcium carbonate. These

satellite plants normally are established at the point of consumption and provide product to a single consumer, usually a pulp mill. The process utilizes waste carbon dioxide from the paper mill.

PCC production from non-captive sources in North America is split between Pfizer Inc. (at Adams, Mass. as well as several satellite plants) and the Mississippi Lime Co. operation. Other companies, such as the Olin Corp., also has the technology available for the open market but are not producers. Most of the PCC produced in the United States is used in paper coating or filling. Smaller amounts are used in both paint and plastics markets with lesser quantities used in pharmaceuticals and adhesives. The plastics and adhesives markets generally require coated grades of product. Pfizer is the only North American producer of coated PCC but about 10,000 tonnes per year is imported from Britain and Japan (Dickson, 1987).

The evaluation of the cost of a precipitated calcium carbonate facility which was conducted in Chapter 3 suggests PCC production warrants further evaluation. The calculations indicate a capital investment in the order of $560,000 to $608,000 (depending on daily operating hours) would be required for a 12,000 tonnes per year operation. The calculations were based on conversion of quicklime by the carbonation method.

Quicklime is produced by calcining limestone in a large kiln. There is one such operation in the Province at present. Purchase of quicklime from this operation could be possible (this option was not addressed in the study), but transportation and handling costs would favour an on-site operation.

A potential producer without access to a supply of quicklime would have to assess the economics from a different viewpoint and bring the capital cost of a kiln into consideration. An alternative would be to evaluate advances in grinding technology in order to produce a ground product with a similar particle size as PCC.

In view of the existing carbonate industry in the Province combined with reasonable market potential in the study area, it would appear production of filler products from carbonate has the best potential of the four minerals included in the study. An existing tariff of 3.1% on the import of calcium carbonate fillers into the United States is scheduled to be removed by 1993 under the terms of the Free Trade Agreement (Harben, 1988) and is an additional positive factor.

7.6.3 Kaolin

Kaolin is not currently produced in the Province but has the potential to be extracted from unused materials currently being stockpiled by a silica producer. The major market for kaolin is the paper industry. As previously discussed a significant component of this market is situated in relatively close proximity to New Brunswick. In addition, most of the paper industry in the study area continues to use the acid sizing process which requires kaolin as a filler.

It would appear that the major constraint to development would be the ability to produce a product of acceptable quality. If this can be achieved, the market would have to be actively pursued to overcome the established business relationships of the companies which

currently supply the kaolin.

7.6.4 Silica

There is established silica production in the Province but production of sufficiently fine material to meet filler requirements is not practiced. The major market for silica fillers is the paint industry but the industry within, or in close proximity to, the Province is relatively small. In addition existing suppliers of silica fillers are firmly entrenched in the marketplace. The combination of these factors suggests that development of a silica filler industry in the Province is unlikely in the foreseeable future.

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